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# ANNUAL REPORT

OF THE

## BOARD OF HARBOR COMMISSIONERS

FOR

THE YEAR 1877.

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# Commonwealth of Massachusetts.

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## HARBOR COMMISSIONERS' REPORT.

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*To the Honorable the Senate and the House of Representatives of the Commonwealth of Massachusetts.*

THE Board of Harbor Commissioners, in accordance with the provisions of law, respectfully submit their annual Report.

By the operation of chapter 213 of the Acts of 1877, the number of the Board was reduced from five to three members. The members of the present Board, having been appointed under the provisions of said Act, were qualified, and entered upon their duties on the second day of July. The engineers employed by the former Board were continued, and the same relations to the United States Advisory Council established. It was sought to make no change in the course of proceeding, and no interruption of works in progress or matters pending; and the present Report embraces the business of the entire year.

### SOUTH BOSTON FLATS.

The Board is happy to announce the substantial completion of the contracts with Messrs. Clapp & Ballou for the enclosure and filling of what has been known as the *Twenty-five-acre piece* of South Boston Flats, near the junction of the Fort Point and Main Channels, which the Commonwealth by legislation of 1867 (chapter 354) undertook to reclaim with material taken for the most part from the bottom of the harbor.

In previous reports, more especially the tenth of the series, the twofold purpose of this work, which contemplated a har-

bor improvement and the creation of new territory adjacent, has been fully discussed, with a review of the legislation which preceded the contracts above referred to; and there remains now to inquire whether the intent of the Commonwealth has been carried out in the manner prescribed, and to the ends proposed.

It was expected, at the time that the Commonwealth entered upon this work, that the value of the territory reclaimed would much more than offset the cost of the enterprise, including the harbor improvement, which was its primary object; and, until the recent general decline of real estate throughout the country, the Board, upon well-founded information, remained confident that these expectations would be realized. At the present moment, no correct estimate can be made of the market value of this property; but since there is little reason to doubt that the trade of Boston will share in the general revival of business, whenever that may happily occur, the hope may still be entertained that the reclamation of the flats will prove a financial success. Meantime, and awaiting the return of better days, the Commonwealth may congratulate itself upon having initiated a harbor improvement, which, in conjunction with that undertaken by the General Government, has already greatly enlarged the commercial advantages, and increased the navigable facilities of the port.

It will be remembered that the site of the present reclaimed land was formerly a slough grown over with sea-grass, laid bare at lowest tides; and that the site of the present ship-channel in front of this property was much of it equally shallow. A half million of cubic yards of material has been dredged from the harbor-bed to fill the territory, most of which came from parts of the harbor in front, not before navigable, and all of it from ground heretofore too shallow for heavy ships. Had the purpose been exclusively an improvement of navigation, the great volume of dredging we have named would be a direct and absolute measure of harbor improvement; but as the utilization of the territory to be reclaimed entered also into the problem, the dredging has been so disposed as to secure the best results for the harbor, consistent with the construction of a deep and ample avenue from the new territory to the sea. The Board invites attention to the map, showing the space from which shoals

have been removed, in support of the above view; but it must be borne in mind that the efforts of the Commonwealth were expected to be supplemented by the requirements of other parties to whom grants of flats should be made, and that the entire removal of the shoal which now in greater part remains at the mouth of the Fort Point Channel would by this time have been accomplished. The heavy wall which has been built at the turn of the reclaimed territory, as we leave Fort Point Channel, was set back about 850 feet from the extreme point of the flats, awash at low spring tides, and the 23-foot channel dredged along this wall, converting this point into an isolated shoal, is here only about 250 feet wide. The entire removal of this shoal would be a boon to the commercial interests of the eastern water-front of the city, out of all proportion to the cost which it would involve.

The report of Mr. Edward S. Philbrick, engineer in charge, which will be found in the appendix, discusses carefully and frankly all the elements which enter into the construction of the walls which retain the filling and form the frontage upon Fort Point Channel and the harbor proper, and adds statements of the payments made to the contractors as the work progressed.

Few great works of engineering in tidal harbors have been preceded by more careful inquiries into the appliances to be used with best economy and safety, than the history of this work reveals. The character of the walls which should be built, upon a somewhat treacherous bottom, and yet capable of sustaining an immense lateral pressure, had been a subject of study with engineers during ten years prior to the practical commencement of operations; and the plans adopted may be regarded as the fruit of the best talent in the profession. Mr. Philbrick's computations of stability for the walls completed, argues that no margin for further economy as regards weights and dimensions has existed.

The greatest danger to which the retaining walls, just completed, could be subjected from the pressure of the filling, has already been encountered, in the opinion of the engineer, who believes that the most critical period was that during which the clay dredged from the harbor remained as a semi-fluid mass behind the walls. A practical lesson brought this matter to the attention of the engineer in the first com-

plete fillings that were attempted within the light wall. "Early after its completion, this wall was filled up to grade 13 with clay, and a huge pile was left temporarily at a higher level near the beginning of the curve. Directly afterwards a forward movement of the wall was observed, about a foot in amount, and tapering out in about 200 feet of length each way. The pile of clay was soon removed by spreading on to adjacent spaces, and no further movement has been detected here since."

In his subsequent operations the engineer endeavored, as far as practicable, to have the material deposited in layers, and suffered to become compact from layer to layer. In this way all further pushing outward was avoided, except slight movements of the dock walls, owing to too rapid filling during the last season when the work was hastening to its close.

The heavy wall at the curve facing the harbor, immediately in front of which there is now from 19 to 23 feet of water at low tide, is founded upon rubble, and has therefore been subject to some settlement as the angular stones below have worked into the clay bottom. This was foreseen, it having been uniformly the experience with this system of building heretofore. "It is now a year since it was loaded by the filling, and its stability has been quite satisfactory." Mr. Philbrick furnishes tables showing the settlement of the lower course of this heavy wall and the present elevation of the coping, from which it appears that the settlement varied from a maximum of 1.07 feet to a minimum of 0.49 feet. The average height of the coping is now 15.62 feet, or 0.38 below the intended grade.

Between the State Dock and the dock under construction by the Boston and Albany Railroad Company, there is a heavy wall of rather different construction from the one at the curve, just commented upon. Instead of resting upon a considerable elevation of rubble, the wall in question is based upon broken stone carefully packed and levelled in a trench dredged three or four feet below the bottom, as it was destined to be in front. This wall has but recently been completed and loaded from behind; but since the greatest danger was immediately after the filling, it is presumed that the settlement which has occurred, limited to 0.29 feet, is a "guarantee of stability" in future. The coping of this



heavy wall varies in elevation from 16.02 to 16.17, with an average elevation of 16.08.

Mr. Philbrick makes the stability of the heavy wall between the docks the subject of an essay, which we have desired him to present in his report, appended, because of its value as formulated experience, likely to be particularly useful in the event of any future enclosures of the flats; and because it illustrates what we believe to be the fact, that no less massive walls and no less careful execution of the work would have answered the purpose.

The area reclaimed, measured within the outer edges of the copings of the retaining walls, is 898,794 square feet, or 20.64 acres, with a dock, whose additional area is 159,947 square feet, or 3.67 acres. These spaces, added to the outlying bases of the walls, make up the *twenty-five-acre-piece*, as this territory has thus far been called.

The dock just mentioned has length, width, and depth enough for eight ordinary sailing-ships, or four first-class ocean steamers, loading or discharging simultaneously.

The cost of the work, including all reserve under the contracts, has been \$719,063.49, which is an average of nearly 68 cts. per square foot, if we include the dock. If the space occupied by the dock and that reserved for Northern Avenue were to be deducted, the average cost would be  $87\frac{1}{2}$  cts. per square foot nearly.

It is proper to add that some claims are made by the contractors for extras, in the execution of the contracts, which are under consideration, but the amount that will finally be allowed of such claims has not been ascertained.

## SHOALS IN BOSTON UPPER HARBOR.

### *Dredging at East Boston.*

Under the authority vested in the Board, two contracts were made for removing additional portions of the shoal ground off East Boston frontage. A portion lying off the docks of the Cunard Steamship Company has been dredged by the Harbor Improvement Company at the contract price of \$2,800, which has been paid out of the income of the compensation fund appropriated for that purpose, — the work

having been satisfactorily completed in September last. A portion lying off Dock No. 6 of the Grand Junction Wharf property is being dredged by W. S. Fretch & Co., at a contract price of \$8,962.80. Partial payments have been made upon this work as it has progressed; and the contractors state that it will be finished within a few days from the date of this Report.

*Anchorage Shoal.*

This shoal occupies a central portion of the upper harbor basin, and may be regarded as a projecting spur from the Bird Island Shoal. In consequence of a report to the Board by the harbor master, Mr. F. C. Cates, concerning the improper dumping in the channel of dredged material from the Upper Middle which was consigned to Hangman's Ledge, an order was issued by Gen. Thom requiring the contractors committing this damage to dredge an equal amount of material from such part of the harbor as the Board should assign. Under this arrangement 552 cubic yards from the highest or shoalest point of Anchorage Shoal, which lies nearly midway between the South Boston flats and Bird Island, has been removed. This work, however, has but slightly reduced, and only affected a small portion of the shoal, which still remains one of the most serious encumbrances to the harbor.

In his able report to his department, Gen. Thom makes the following mention of this shoal.

Anchorage Shoal (next above the Upper Middle) is now the only remaining obstacle to the free passage of ocean steamers and other deep-draught vessels from the ocean up to the inner harbor of Boston, in all stages of the tide. A recent survey of this shoal shows that it has a very irregular shape, and extends into the main channel chiefly from the East Boston and Bird Island flats, having on its shoalest part but  $15\frac{1}{2}$  feet of water at mean low tide, or about 25 feet at ordinary high water; that the greatest depth that can be carried over its southern part is 22 feet at mean low water for a width of about 350 feet, or 21 feet for a width of 500 feet. To open the channel to a depth of 23 feet at mean low water for a width of 900 feet, the least width that is adequate for this part of the channel, would require about 85,000 cubic yards of dredging over an area of about 80,000 square yards of shoal. Gen. Thom calls the attention of his depart-



ment to the propriety and consistency of having this work done by the General Government in furtherance and completion of the work now so nearly accomplished for the permanent improvement of our harbor.

### *Man-of-War Shoal.*

Connected with the subjects of harbor improvement which the Board has contemplated, the removal of Man-of-War Shoal has received special consideration. As stated in their tenth report, the execution of this important work was deemed appropriate to the General Government, and Congress was memorialized in regard to it; a copy of the memorial being appended to that report. The subject was referred by Congress to the Engineer Department, and by it to Gen. Thom, who has ordered a survey of the shoal, and estimated the amount of material to be removed at 65,000 cubic yards. Gen. Thom recommends and includes this in his general estimate for the works of harbor and coast improvements under his charge, and expresses confidence in the successful issue of the project.

The improvements made under the immediate supervision of the Board in using the income of the compensation fund in dredging have given unobstructed access to three of the largest and most important docks on the East Boston frontage to the largest European steamers which visit the port of Boston. The Cunard Steamship Company, at their own expense, have added to the improvement of the entrance to the dock next eastward from their main pier. It is expected that the entrance to Dock No. 6 of the Grand Junction Wharf property will be deepened by the Boston and Albany Railroad Company.

### PRISON POINT BAY.

Prison Point Bay and Miller's River, between which there is no natural division, form together a tributary tidal basin of the Charles River. This basin lies partly in Cambridge, and partly in the Charlestown district of the city of Boston. It was regarded by the United States Commissioners as an important tidal reservoir, supplying its full proportion of the scouring power which maintains the main channels of the harbor below; and the Board, after repeated inquiries into its

physical condition, as questions connected with its proposed reclamation have arisen, has been unable to discover any ground of doubt as to the value originally assigned to it, except so far as encroachments have diminished its tidal volume.

If we distinguish as *Prison Point Bay* that portion of the basin which lies north-easterly of the Fitchburg Railroad, we find upon the United States Commissioners' chart of 1861, that its area was 68.8 acres at ordinary high tides.

Under the fourth section of the Act of 1866, establishing the Board of Harbor Commissioners, all authorized structures in tide-water of Boston upper harbor upon which work had begun, prior to the passage of this Act, are exempt from assessment for tide-water displaced. From the most careful inquiry, the Board has ascertained that at the date of the Act aforesaid, there remained in Prison Point Bay an area of 64.8 acres over which the Commonwealth retained jurisdiction, at least to the extent of forbidding encroachment without its authority, and requiring compensation for tide-water displaced.

Under an Act of 1867 (chap. 335) the Eastern and Fitchburg railroads jointly sought and obtained from this Board a license to construct certain sea-walls that excluded tide-water not only from their sites, but also from a triangular space of flats lying between said roads. The total area from which tide-water may be excluded under this Act and license, is about 14.5 acres, of which only about 0.6 acres have actually suffered this loss by occupation. Both the original Act and the license granted from the Board, in this case, contained an explicit provision for tidal compensation.

By an Act of Legislature (chap. 253, 1868) the city of Charlestown was authorized to fill so much of Prison Point Bay as lay northward of the Boston and Maine Railroad, provided that compensation should be made for all displacements of tide-water. By this Act a territory of about  $38\frac{1}{2}$  acres was dedicated to reclamation; and it was upon this territory that the Eastern Railroad, by subsequent grant, was authorized to locate roadways, buildings, &c.

The only works undertaken by the city of Charlestown under this Act, and within the purview of the compensation clause, was the construction of Canal Street, and the filling of certain parcels of flats lying between it and the original

shore line of Charlestown Neck. The Board made an assessment for compensation, at the rate of  $37\frac{1}{2}$  cents per cubic yard of tide-water displaced, and collected the same of the city of Boston after the annexation of Charlestown.

In the course of the construction of Canal Street, as aforesaid, certain other parties entered upon lots adjacent to this street on either side, and proceeded to reclaim lands without authority. These parties were notified by the Board to desist till they should procure proper licenses.

By Act of 1873 (chap. 360) and of 1874 (chap. 45) the Eastern Railroad Company was authorized to cross Prison Point Bay, by one or more tracks, and to fill certain flats within the limits of the territory covered by the previous grant (1868) to the city of Charlestown. Upon application from the said Eastern Railroad, a license was issued authorizing the construction of a bridge on piles. This license, which is numbered 207, bears date of April 8, 1874, and contains the usual requirement of compensation for tide-water displaced; and on the 2d of August, 1876, an assessment of \$118 $\frac{13}{100}$  was made upon the company by virtue of said requirement.

In the construction of the bridge, for which alone the Eastern Railroad Company had asked authority, the privileges of the license just mentioned were exhausted; but the Board ascertained that this company was engaged in filling flats adjacent to the newly constructed Canal Street, for which no license had been granted. At a meeting of the Board held Oct. 20, 1875, it was voted that the aforesaid Railroad Company, and all other parties filling without license in Prison Point Bay, should be notified to show cause why legal proceedings should not be instituted against them; and at a meeting of the Board held Nov. 4, 1875, the private parties referred to presented their cases.

On Nov. 11, 1875, the Board voted that plans be required and compensation charged, for all filling outside of Canal Street; but reserved its decision upon cases of filling within the location of said street, for reasons fully stated in the Tenth Annual Report.

By vote of Board dated Nov. 24, 1875, the Attorney-General was requested to file an information against the Eastern Railroad Company, for unlawfully filling flats in Prison



Point Bay, in violation of law; and this information was brought Dec. 1, 1875. Under date of May 8, 1877, the aforesaid Eastern Railroad Company, through its president, Mr. A. P. Rockwell, gave written notice of its intentions regarding the occupation of territory in Prison Point Bay, and subsequently presented duplicate plans.

The Board, having considered the matter maturely, accepted these documents as a proper compliance with the law, and issued a formal license, No. 391, dated Sept. 5, 1877, which will be found, without its accompanying plan, under the list of "Office Work" in this Report. By this license, the Railroad Company was authorized to fill about 18 acres of flats, and all under the expressed obligation to make compensation for tide-water displaced. Thus far only three acres have, however, been reclaimed under this license.

Of the original bay which comprised 64.8 acres subject to the fourth section of the law of 1866 establishing the Board of Harbor Commissioners, 12.8 acres have been filled: there now remain unfilled, 52 acres. Of the 12.8 acres filled, 7.3 acres have been reclaimed without authority; and of the 52 acres still unfilled, 29 acres have been licensed subject to compensation for tide-water displaced: so that there remain only 23 acres of tide-water over which the Commonwealth retains any jurisdiction in the interest of harbor preservation.

The 23 acres referred to above as unfilled and unlicensed, lie in three parcels, as follows, —

Four-tenths of an acre between Canal Street and land belonging to the Eastern Railroad Company.

Eleven and one-tenth acres between the Eastern Railroad freight bridge and the Boston and Maine Railroad.

Eleven and five-tenths acres between Boston and Maine and Eastern Railroads.

Neither of the parcels adjacent to the railroads is likely to be wanted for any other purposes than those connected with the business of these roads.

The private parties to whom we have referred as illegally reclaiming lands in Prison Point Bay outside of Canal Street are understood to claim exemption from the obligation to make compensation for tide-water displaced on the ground that their filling has been done in compliance with an order from the Boston Board of Health, and that said order has

justified all the filling they have done. The Board assumes, however, that no local board of health has jurisdiction to order the filling of tide-water, and that no order from such board could afford any protection to private parties making such filling, but that such filling should be treated precisely as if done without any order.

The following is a tabular statement of the data which have formed the subject of the preceding remarks:

DESIGNATION.	Act of Legislature.		License of Board.		Area.		Depth of Tide.	Area actually filled.		Volume to be displaced. Cub. yds.	Volume actually displaced. Cubic yards.	Volume for which compensation has been received. Cubic yards.
	Chap.	Year.	No.	Year.	Square ft.	A.		Square ft.	A.			
Eastern and Fitchburg Railroads, jointly, .	335	1867	21	1868	632,400	14.5	8.6	26,750	0.6	201,764	8,520	None
City of Charlestown, . . . . .	253	1868	None	None	82,200	1.9	4.6	82,200	1.9	12,107	12,107	12,107
Encroachment by private parties inside Canal Street, . . . . .	None	None	None	None			3.9	159,709	3.7		23,069	None
Encroachment by private parties outside Canal Street, . . . . .	None	None	None	None			6.8	66,500	1.5		16,746	None
Encroachment by the Commonwealth in vicinity of State Prison, . . . . .	None	None	None	None			4.0	79,107	1.8		11,720	None
Boston and Maine Railroad, . . . . .	None	None	None	None			7.0	13,500	0.3		3,500	None
Eastern Railroad, . . . . .	360 45	1873 1874	207 391	1874 1877	787,565	18.1	8.1	129,636	3.0	236,269	38,891	None



## CHARLES RIVER BASIN.

By a Resolve of the last Legislature, chapter 37, the Board was required to investigate and report concerning the harbor line on the northerly side of Charles River, and the expediency of changing it. In pursuance of this resolution, notice was given as required by the statute of 1866; and, after full investigation and hearing of parties interested in this portion of the harbor frontage, the Board submits the following: —

The harbor-line previously modified from the old line of 1847, and re-established by the Legislature of 1873, was based upon the reservoir capacity of the basin, the line prescribed being the one deemed most practically useful for occupation, while preserving the tidal volume of the basin by a balance of quantities between fillings and excavations. In the study and solution of this problem the basin between West Boston and Brookline bridges was considered as a unit, the irregularities of outline being so generalized, or equated, as to give a symmetrical form to this water-area as a permanent inner basin of the harbor. This scheme contemplated as much advantage to individual littoral proprietors in the betterment of land and water frontage, as in physical and commercial advantage to the harbor and the public.

It has been claimed by certain shore proprietors that their rights have been affected in cutting off certain salient points which are or were upland, by this line of 1873.

A line which would avoid encroachment upon the salient points in the shore line, and yet retain the tidal prism of the basin, would be so irregular and unsuited to utilization of either land or water frontage, that the Board does not deem it a desirable project.

The alternative scheme which the Board suggests, and which is shown on the accompanying plan, is a straight line between two of the initial points in the harbor-line of 1847, one being at the westerly abutment on the southerly side of West Boston Bridge, which at this point joins and coincides with the established line running northerly to Cragie Bridge; and the other being at the point "on the northerly shore of Charles River near its mouth." From this coincident point with the harbor line of 1847, which here terminates, the line is continued to a point on the easterly side of Brookline

Bridge, 110 feet southerly from the present solid abutment of the bridge on this side of the river. The Board has determined upon this extension of the line and this terminal point as being practically in harmony with a scheme of harbor lines for the upper reaches of the river, should such in future be required, and also because the claims of all shore proprietors for encroachment upon what is asserted to be former upland are by this modification adjusted and satisfied. This continued portion of the line leaves a channel width at Brookline Bridge between it and the harbor line on the southerly side of the river of 550 feet. The width between the solid abutments of the River-Street Bridge, next above, is 350 feet; and the width between the harbor lines at the "mouth of the river" before named, below Brookline Bridge, is 700 feet.

In presenting the scheme devised and adopted in 1873, for the reconsideration of the Legislature, the Board would quote from the argument of Professor Whiting in his report of that year.

"As a fundamental principle in the study of this subject, regard has been had to the maintenance of the tidal prism of the basin as the basis of any scheme of harbor lines to be devised. It would be contrary to the established and acknowledged physical relations of the upper reservoirs to the lower channels of the harbor, and in direct opposition to the judgment of the United States Advisory Council to deviate from this rule or law of tidal power. The occupation of the tidal prism by the existing flats of the basin amounts to about 1,460,000 cubic yards. It remains, therefore, to make such adjustment of harbor lines as will leave this amount of tidal reservoir capacity intact. This can be done by transposing the shallow water-spaces within, and the flats without these lines; in other words, to determine such harbor lines as will preserve the present tidal prism of the basin, by making the excavations outside of them to the plane of low water, equal to, or balance, the fillings within the same lines to the plane of high water. By the lines presented the amount of gain by excavation outside of them will about equal the amount of the present tidal prism of the basin, 1,460,000 cubic yards. The amount of loss by filling within these lines will equal about 1,455,000 cubic yards,

leaving a slight contingent balance in favor of the scheme. In the adjustment of the lines, regard has been had to natural and harmonious lines of flowage as well as those practical and useful for utilization, both in land and water improvements."

#### RE-SURVEY OF THE WHARF-LINES OF BOSTON UPPER HARBOR.

By chapter 91 of the "Acts and Resolves of Massachusetts, 1877," a sum not exceeding \$5,000, was appropriated to be expended under the direction of the Harbor Commissioners, for the re-survey of the wharf-lines of Boston Upper Harbor.

At the outset, the Board had relied upon making an arrangement with the superintendent of the Coast Survey, by which the survey might be executed by officers of that service, specially detailed by him; but in August, apprehending that this arrangement could not be made, the execution of the triangulation was assigned to Mr. W. E. McClintock. However, during the following month, the co-operation of the Coast Survey was obtained; and the work, therefore, as originally planned, was transferred to its representative officers, Messrs. Professor Henry L. Whiting and Francis Blake, jun., who were specially assigned to duty by the Hon. C. P. Patterson, Superintendent United States Coast Survey, the former to supervise the topographical survey, and the latter to execute the triangulation. Mr. McClintock was retained as chief-assistant.

The triangulation was begun late in September, and, having been diligently prosecuted during the last three months, is now nearly finished. Twenty-seven signals have been erected, twenty-one stations occupied, and nearly 5,000 angular measurements made. The principal stations occupied have been marked by substantial granite monuments, which will greatly facilitate the reference of any future changes in the harbor lines to the survey. During its progress, much interest has been shown in the work by engineers in our vicinity. Applications have been made for the geodetic establishment of points to be used in local surveys; and these requests have been complied with so far as could be done without entailing additional expense upon the survey.

Mr. Blake, assisted by Mr. McClintock, is now engaged in computing the field observations, and will, in a few weeks, present a full report of the work, together with its records, computations, and final results.

The scheme for the topographical survey has already been perfected, and all preliminary arrangements have been made, so that the field-work will be pushed to as speedy a completion as the weather may allow.

The hydrography is being executed under the direction of Mr. D. Koppmann, Engineer of the Board, assisted by Mr. Wm. T. Blunt. From August to November, inclusive, a party was engaged in making careful soundings in and around the docks from Dover Street Bridge to Grand Junction Wharves, including the frontage of the city proper, Charlestown, and East Boston. As soon as the weather may permit, these soundings will be extended so as to include the entire frontage embraced by the topographical survey.

#### COMPENSATION FOR TIDE-WATER DISPLACED.

By an order of the Legislature of 1877, the Harbor Commissioners were directed to consider and report to the present Legislature "whether any change, and what, is necessary in the law relating to compensation for tide-water displaced." The subject of compensation for tide-water displaced is familiar to all who have made the preservation and improvement of the harbors of the Commonwealth a study, but may be less so to those who have given these matters only general attention; and it may be useful to recur to the principles upon which the legislation in relation to it rests, in connection with an examination to determine whether any modification of such legislation is required. The value of tide-water rests upon the principle that the size of the channel, *i.e.*, the area of its cross section, depends, in alluvial bottoms, upon the service that such channel performs as an aqueduct; that the tidal inflow and outflow by its scouring action maintains the channel, so that any diminution of a tidal basin diminishes the force which preserves the channel below. Eminent engineers, designated by the United States authorities to study this problem, advised, many years since, that encroachments upon the tidal area of the upper harbor of Boston or its interior



basins should be permitted only upon condition that an equal volume of tide-water should be provided by excavation elsewhere. This was termed compensation in kind.

Chapter 149 of the Acts of 1866, by which the Harbor Commission was established, contains in its fourth section the following provision : —

“ The amount of tide-water displaced by any structure or filling of flats hereafter authorized as aforesaid shall be ascertained by the Harbor Commissioners; and they shall in all cases affecting the harbor of Boston, and in cases affecting other harbors if they shall deem it necessary, require the parties making the same to make compensation therefor, either by excavating in some part of the same harbor where the work is performed, including tide-water channels between high and low water mark, to such an extent as to create a basin for as much tide-water as may be displaced by such structure or filling of flats ; and the same shall be done under their direction : or by paying, in lieu of performing the work of dredging to restore the displaced tide-water, a sufficient sum of money for making such compensation, or by improving the harbor in any other mode to the satisfaction of the Commissioners; and all money thus paid shall be paid into the treasury of the Commonwealth, and be reserved as a compensation fund for the harbor where such compensation is to be made, and used for that purpose under the direction of the Commissioners : *provided*, that all dredging made for purposes of such compensation for displaced tide-water shall in no wise injure any existing channels, but, as far as practicable, shall be directed towards their permanent improvement.”

This provision constitutes the present legislation upon the subject of tide-water displaced. It leaves to the discretion of the Harbor Commissioners whether, in any particular case of encroachment, the best economy would lie in actual replacement of tide-water by excavation elsewhere, or in the execution of some equivalent improvement in the harbor. It is clear that, in many portions of the channel-ways, it is not the area of the section that is insufficient, but only one of the elements for computing this area, — width, or depth ; so that not all the change induced by the loss of tide-water requires to be offset, but only that which is injurious to navigation. Such cases are so nearly the rule in Boston Harbor, that the plan of creating a fund, by the expenditure of which a greater economy could be effected in compensation, has been followed, except where those having grants have elected to make compensation by dredging. Material taken from the harbor has been recently in demand for filling, because cheaper than

earth brought from the country; and this has induced some parties to prefer making compensation in work rather than money.

It is obvious that the repair of the injury inflicted by encroachment is all that was originally contemplated in the requirement of compensation in kind, and all that would be accomplished by the payment of money, if expended by the State for no other purpose than to make such compensation in kind; but it is in the highest degree equitable that those to whom the public grants favors in any harbor, and who are in the long run those who derive most benefit from the harbor, should contribute for its improvement, as well as its preservation, in proportion to the favors they receive. Certainly none could complain of this so long as the limit of the requirement is the cost to the public of restoring to the harbor what is taken from it. When other harbor improvements are made in lieu of compensation in kind, permanent gain to the harbor is often secured without increase of the burden to those of whom compensation is required; and when the money equivalent of compensation in kind is paid, and the fund thus derived is applied directly to the removal of shoaling injurious to navigation, a gain is made in like manner by the greater economy of such application.

The statute makes compensation in some form imperative in the harbor of Boston; but with the other harbors of the Commonwealth it is discretionary with the Harbor Commissioners. It is plain that the encroachments upon tidal areas will be greatest where business centres, and land becomes in consequence greatly enhanced in value; and thus the injury, which in many other harbors is inappreciable, becomes serious. It is also apparent that the value of a harbor at such business centre is much greater, and that even slight variations in the depth of approaches may determine the admission or exclusion of entire classes of vessels of vital importance to business. The large expenditure of the General Government for the preservation and improvement of the harbor of Boston has increased the obligation of the Commonwealth to exercise its control of tide-waters there in such a manner as in no case to hinder these objects, and, so far as may be, to aid them; and the policy by which the State has sought to supplement the work of the United States has been of great service in securing the liberal action of the latter.



These considerations, and others which might be suggested, fully justify the discrimination which the present statute makes between the harbor of Boston and the other harbors of the Commonwealth; but they also suggest a reason for modifying the rigidity of the present statute in cases where money is accepted in lieu of compensation in kind. It is assumed that the present statute requires such money payment to be sufficient to enable the Commonwealth to restore the tidal volume. In many instances this would be prohibitive of the utilization of the harbor, and thus defeat the only object in its protection or improvement. It is, however, very desirable that provision should be made in all important harbors to repair the mischief of gradual encroachments.

It is fair to presume that most of the harbors of the Commonwealth will have greater value in the future than they now have; and the policy of the State in regard to them should be that which will be wise for the long period. A fund such as the present use of the harbor is sufficient to create may seem insignificant; but, if left to accumulate, such fund may become very considerable by the time a greater use of the harbor should justify expenditure from it. The Board would recommend that the amount required for compensation, when paid in money, be limited to a maximum of thirty-seven and a-half cents per cubic yard of tide-water displaced, which is the price heretofore charged, but that power be given to accept less rates. There should be power to accept different rates, not only for different harbors, but for different parts of the same harbor. The occasion for discrimination on both grounds, the injury inflicted, and the value of privilege granted, is often as striking in different parts of the same harbor as in different harbors.

When the displacement of tide-water is permitted for public purposes, it would seem just that the payment should be the minimum sufficient to repair the injury occasioned. The displacement from interior reservoirs should, upon the principle established, be followed by a corresponding diminution of the channels below, all the way to the sea; but practically, the only injury done is at the points where the widths or depths are now equal to, or less than, the requirements of navigation, so that the channel dredging to be done artificially is less than that which nature would execute with

the force which is abstracted. Although the practical repair of damages occasioned by encroachment involves, as a rule, less work than the restoration of tide-water displaced, the Board are not prepared to admit that the cost of such repair, and permanent maintenance of channel depths, would in all cases be less. No principle upon which discrimination can be made between different harbors, or between different parts of the same harbor, could be applied with absolute accuracy; but it is believed that a closer approximation to an equitable assessment could be made by discrimination than by a rigid rule of uniformity.

The existing statute permits expenditure from the compensation fund, under the direction of the Harbor Commissioners, for compensation in kind, but does not contain authority for expenditure to repair injury by dredging otherwise; and, in practice, special legislative authority has been obtained for every expenditure thus far made. The statute is defective, both in what it permits and what it does not permit. The injury to harbors by the reduction of tidal volume is permanent; and the provision for compensatory repairs should be of a permanent character. Expenditure from the principal of the fund for any form of compensation should not be permitted except upon an exigency to be met by special action of the Legislature; but there should be authority in the Harbor Commission to expend the income of the fund for compensatory improvements as well as for compensation in kind.

#### BASS AND GURNET ROCKS.

In pursuance of the Resolution passed by the last Legislature in relation to a contemplated removal of Bass and Gurnet Rocks, off Gurnet Head, at the entrance of Plymouth and Duxbury Harbors, the Board have investigated the subject referred to them, have visited the ground in question, and had a survey made by their engineers of the locality, so far as to determine the position of the respective rocks and the depth of water upon and around them. Gurnet Rock is situated about 1,400 feet from the head, and bears about S.S.E. from the lights; it has four (4) feet of water upon it at mean low tide, and is surrounded by a depth of from  $15\frac{1}{2}$  to 19 feet of water. Bass Rock is situated about 1,550 feet

from Gurnet Head, and bears about S.  $\frac{1}{2}$  W. from the lights; it has three and one-half ( $3\frac{1}{2}$ ) feet of water upon it at mean low tide, and is surrounded by a depth of  $15\frac{1}{2}$  to  $17\frac{1}{4}$  feet of water. The soundings of the U.S. Coast Survey made in 1853, agree substantially with those taken by our engineers in November last, excepting, that immediately around and outside of each rock their soundings give more water than those of the Coast Survey, indicating that a slight deepening has taken place along the outer margin of the shoal off Gurnet Head during the last twenty-five years. The depth of water upon the rocks themselves agrees exactly with that given by the Coast Survey. Gurnet and Bass Rocks are well and long known objects at the entrance of Plymouth Harbor, and are named and marked by buoys on the charts of the Coast Survey of 1857, where they are shown to be situated near, but within the irregular outline of the shoal ground off Gurnet Head, as indicated by the conventional signs of the survey, each rock being upon a salient point of the shoal with another point of shoal between them, having but 10 feet of water; which projects into the channel beyond the range-line from rock to rock. The width of channel outside of the three-fathom lines of the Coast Survey between the buoy at Gurnet Rock and that on the easterly point of Brown's Island is 3,700 feet; between Bass Rock buoy and Brown's Island, 1,800 feet. Opposite the second buoy (No. 3) on Brown's Island, the channel is 1,500 feet, continuing at this, and a slightly greater width, for about  $1\frac{1}{4}$  miles toward the Cow-yard anchorage.

The approaches to this channel are by the unobstructed open waters of Massachusetts Bay. The entrance off Gurnet Head, and the navigable room within it for a distance of about three miles to abreast of the point of Long Beach, are fairly favorable, and may be ranked as above the average in relation to the inner waters to which it leads. While Gurnet and Bass Rocks are dangerous objects, lying in a depth of water sufficient to allow a large-sized vessel to run upon them, their positions, as before stated, are not within the channel proper, but on the margin of the shoal ground forming its northern boundary. They would, therefore, be characterized as off-lying dangers pertaining to a rocky headland which should not be approached within the certain



limits indicated by charts and buoys, unless under the guidance of a pilot. The removal of these rocks would not materially improve or enlarge the *channel*, as the nature and outlines of the shoal upon which they are situated would not admit of setting the buoys, which define it, further back.

From the data in its possession, and from the fact that other important works affecting the preservation of Plymouth and Duxbury Harbors require aid from the General Government, the Board feels justified in construing the purport of the Resolution of the last Legislature as referring the application to Congress to their discretion, and to report it inexpedient, at this particular time, to apply to Congress for a special appropriation for the removal of Bass and Gurnet Rocks.

#### GREEN HARBOR RIVER.

The Board exercised its authority in relation to Green Harbor River, in notifying and requiring the proprietors of its marshes, mentioned in section 4 of chapter 303 of the Acts of 1871, to remove the shoaling and other obstructions from the channel of Green Harbor River and its approaches. The terms and conditions of this notice and requirement were recited in their eleventh report, pages 11, 12, 13. No action has been taken on the part of the marsh proprietors under this notice.

By chapter 219 of the Acts of 1877 the Attorney-General was authorized and directed, upon the petition or request of the Harbor Commissioners, to bring, in the name and behalf of the Commonwealth, a bill in equity, or other proper process, to compel any and all parties liable under chapter 303 of the Acts of 1871 so to do, to remove the shoaling or other obstructions in the channel in Green Harbor River. The Board, acting under this statute, have made the requisite petition to the Attorney-General, and the respective rights and obligations of the parties will in due time be determined by the courts.

The Board visited Green Harbor River in October last, and examined the condition of the channel and inner water spaces. The comparison made, without actual measurements, between their condition at that time and when the survey of the Board was made in 1876, shows changes in accordance with the predictions of Professor Mitchell, and the published

comments of the Board in regard to the possible effect of the dike, before that structure was built.

It is evident that sands have been, and are, encroaching upon the inner water-spaces; and the crest of the bar seems to be rising, and working inward. A small channel, similar to that existing when the last survey was made, still finds its way through the shoals and bar to the sea.

GOVERNMENT WORK OF THE UNITED STATES ENGINEERS  
IN BOSTON HARBOR, AND ON THE EASTERN COAST  
OF MASSACHUSETTS.

By the courtesy of Gen. George Thom, the Board has received a manuscript copy of his report upon the works under his charge in Massachusetts, up to Dec. 31, 1877.

The following is a brief summary of this important service, which has been so ably rendered by both Gen. Thom and Gen. Warren. Their reports in full detail upon their respective works in Massachusetts will be found in the Appendix.

*Boston Harbor.*

The additional work projected for the improvement of this harbor during the season of 1877, under the appropriation made therefor by Congress in the River and Harbor Act of Aug. 14, 1876, was as follows, viz.:—

1. Widening, straightening, and deepening the Main Ship Channel at and near the south-west point of Lovell's Island, so as to have a depth of 23 feet at mean low-water (or about  $32\frac{1}{2}$  feet at mean high-water), for a width of not less than 600 feet, requiring about 30,000 cubic yards of dredging.
2. Breaking up and removing about 290 cubic yards of sunken ledge lying in the Main Ship Channel at the Upper Middle Bar, and near Kelly's Rock; and
3. The removal of numerous sunken rocks (bowlders and ledge) scattered over Nash's Rock Shoal, situated in the entrance of Boston Harbor, so as to have a depth of not less than 21 feet throughout at mean low-water, giving an increase of about 6 feet over its shoalest parts.

The dredging at and near the south-west point of Lovell's

Island was satisfactorily completed under contract, in September last. This improvement, together with the dredging completed in 1875 at the south-east point of Lovell's Island, and that in 1876 at the west end of Great Brewster Spit, and at the Upper Middle Bar, finishes all the dredging hitherto projected for the improvement of this harbor from its entrance up to Anchorage Shoal, giving a channel not less than 600 feet in width and 23 feet in depth at mean low water (or about  $32\frac{1}{2}$  feet at ordinary high water) except where obstructed by the sunken ledges recently discovered near Kelly's Rock, and in the Upper Middle Channel yet to be removed.

A contract has been entered into for the breaking up and removal of the sunken ledge in the Upper Middle Channel (which was laid bare last season by dredging) containing  $81\frac{1}{2}$  cubic yards of rock; and also for the breaking up and removal of about 200 yards of the sunken ledge near Kelly's Rock. Operations under this contract were begun in June last, and portions of the ledge near Kelly's Rock have been removed to grade (23 feet at mean low water); but owing to the very unfavorable weather for operations in so exposed a position, work has been suspended till next season.

The work for the improvement of Nash's Rock Shoal was in progress from Sept. 4 to Nov. 8, during which time about 320 tons of large bowlders were removed by a submarine party, leaving only about 40 tons to be removed for the completion of the work next season. These operations have so far improved this shoal, that on its shoalest parts there is now a depth of  $18\frac{1}{2}$  feet at mean low water, being an increase of over 3 feet.

Allusion has already been made to Gen. Thom's consideration of Man-of-War and Anchorage shoals.

#### *Merrimac River.*

Under Gen. Thom's direction, the channel of this river has been greatly improved during the past season by the removal of dangerous sunken bowlders near Silby's Island.

#### *Provincetown Harbor.*

By the appropriation of \$4,000, made by Congress in 1876, all the works that have been projected for the preservation

and improvement of the harbor have now been completed and are in excellent condition.

GOVERNMENT WORK OF THE UNITED STATES ENGINEERS  
ON THE SOUTHERN COAST OF MASSACHUSETTS.

By the courtesy of Gen. G. K. Warren, the Board has received a printed copy of his report upon the works under his charge in Massachusetts, up to July 2, 1877.

*Wareham Harbor.*

The improvement designed for this harbor consisted mainly in dredging the channel of approach to a depth of 9 feet at mean low water; and in widening and straightening it. This has been completed during the past fiscal year, to an extent greater than was designed, owing to a reduction in the cost of dredging. With the unexpended balance, it is proposed to build sand-catchers upon Long Beach, to arrest the sand which drifts over the beach into the harbor.

Nine feet at mean low water, or  $12\frac{9}{10}$  feet at mean high water, can now be carried by vessels up to the wharves; and the width is nowhere less than 100 feet, gradually widening from the wharves outward.

*New Bedford Harbor.*

No work was done here during the past fiscal year, for want of funds, as the appropriation of \$10,000 in the River and Harbor Act, of Aug. 14, 1876, was not made available until April 30, 1877.

A contract has been entered into for dredging, at so low a price that it is thought the projected channel of 200 feet width and 15 feet depth at mean low water can be completed with the funds now available.

*Taunton River.*

During the fiscal year, 93 cubic yards of rocks were removed from "The Nook" and Peter's Point. An appropriation of \$5,000 is needed to complete the channel of 60 feet width and 9 feet depth at mean high water.



*Fall River Harbor.*

No work was done here during the fiscal year, for want of funds. A contract has been made to continue the dredging with the appropriation of \$10,000 of the Act of Aug. 14, 1876, which, it is thought, will complete the improvement originally designed. This improvement is for the benefit of the commerce of the port, and probably nothing more is needed at present.

The fall in prices has enabled the government to do the work at much lower rates than at first anticipated.

The estimate was \$45,000. The appropriations have amounted to \$30,000.

## DUMPING OF ASHES AND CINDERS.

Some annoyance has occurred from improper dumping of ashes and cinders from steamers in the upper harbor of Boston; and serious injury to the harbor would follow if the practice were continued. An effort has been made to prevent it, by assigning a suitable place for such dumping, upon the flats at South Boston. Capt. Cates, the harbor-master, has co-operated cordially with the Board in these efforts; and his zeal and watchfulness have been attended with a good degree of success.

## COMPENSATION FUND FOR BOSTON HARBOR.

The following amount represents the capital of the compensation fund for Boston Harbor, as accumulated up to Dec. 31, 1877: \$114,796.36.

To cover works of improvement in the harbor desirable to be carried forward, the Board recommend the re-appropriation of the unexpended balance of the appropriation authorized by chapter 119 of the Acts of 1876, together with the appropriation of the income from the compensation fund for the current year.

## EXTENT AND CHARACTER OF THE SHORE LINE OF MASSACHUSETTS.

The inquiry following the order of the Legislature of 1875, that the Harbor Commissioners should make an

approximate statement of the location and amount of flats owned by the Commonwealth on its coast and harbors, led to a collection of data by Prof. H. L. Whiting, relating to the extent and nature of the coast and harbors of the State, which the Board desire to incorporate in this Report.

The geographical formation and position of Massachusetts are peculiar, and make one of the prominent capes on the Atlantic coast of the continent. At or near its most salient point, Cape Cod, and the off-lying islands of Nantucket and Martha's Vineyard, occurs a remarkable phenomenon in the variation of the tidal waves of the Atlantic Ocean, which here meet, with a greater inequality in time and magnitude than at any other point upon the coast. This difference is markedly illustrated by the fact that at Provincetown, where the northern wave has the main effect, the rise and fall of the tide is nine and a half feet; while at Nantucket south shore, which is under the influence of the southern wave, the rise and fall of the tide is one and one-half feet. These points are but about sixty miles apart, with nothing between them to break the free undulations of the ocean. The difference in time between these two tidal waves in these sixty miles is greater than that occurring between Cape Cod and Greenland, or Nantucket and Florida. The difference in the temperature of the waters brought together by these tidal waves is also large. The mean result of a summer's observations, made by Professor Mitchell of the Coast Survey, gives 52° of Fahrenheit in Massachusetts Bay, and 72° in Buzzard's Bay. These waters flow within eight miles of each other, on either side of the isthmus of Cape Cod. In these commingling tides are strong and complicated currents, which sweep among the shoals and reefs that surround the Cape and its off-lying islands. The influences of the Gulf Stream, the differences of temperature, and other causes, probably take part in creating the fog which hangs so heavily over the land and water in this locality at certain seasons of the year. With these phenomena so seriously affecting the navigation, there passes around Cape Cod one of the largest fleets of the world, probably only second to that of the English Channel. Most fortunately for the safety of this fleet, nature has provided two important harbors of refuge;

one, Provincetown Harbor, at the northern borders of the dangerous ground, and the other, Vineyard Haven, near its southern or western limits. Besides these more frequented roadsteads, there are other valuable harbors in this section of the State, — Tarpaulin Cove, Wood's Holl, Edgartown Harbor, Hyannis Breakwater, and Monomoy, each affording its peculiar shelter. Whatever forces may have originally formed the undulating ground of the Cape, and the islands to the southward, constant waste of their headlands and bluffs has been going on for many centuries; and the material abraded has gone to compose the shoals and ribs which make the navigation of this portion of the New England coast so dangerous. As a consequence and necessity of these conditions, Massachusetts has a greater number of light-houses, light-ships, bell-boats, beacons, buoys, and fog and danger signals than any State of the Union in proportion to her territory.

Nor is it her more salient cape and its surrounding dangers that give the only importance to the Massachusetts coast. Cape Ann, forming the northern arm and headland of Massachusetts Bay, is a rocky and dreaded point; and here, too, nature has again provided one of the best shelters offered by New England shores, in the safe and accessible waters of Gloucester Harbor.

In Boston Harbor, Massachusetts possesses one the finest sea-ports of the Atlantic coast; in commercial importance ranking second in the list. No more appropriate comment can be made, in relation to this harbor, than to quote from one of the able reports to the Board by Professor Henry Mitchell, when the subject of the protection of its headlands was under consideration. Professor Mitchell says:—

“The great merit of Boston Harbor lies in a happy conjunction of many favorable elements, among which we may distinguish as most important, the facility and safety of its approaches, the ample width and depth of its entrances, and, above all, the shelter and tranquillity of its roadsteads. Perhaps there is no other harbor in the world where the inlets from the ocean are better adjusted to the amplitude of the interior basins, or whose excellent holding-grounds are so easy of access and yet so land-locked. I quote from the highest authority in my profession when I declare that the primary requisite for a good harbor is that *‘the internal area should bear such a relation to the width of entrance as to produce a sufficient degree of tranquillity.’* (Stevenson on Harbors.) And so

difficult has it been to properly adjust this relation in artificial harbors that nearly one-half of all these works may be set down as failures, because the entrances are either too narrow to admit vessels under trying circumstances, or the interior reservoirs too small to dissipate the waves that run in from the sea. In natural harbors, where the primary requisite cited above is fulfilled, it often happens that the interior basin is so large, that the local effects of strong winds are sources of discomfort and even danger, as in San Francisco. Boston Harbor has no such drawbacks: her interior water-space is large, but is divided by chains of islands into basins which offer sufficient room for the heaviest ships to ride freely at anchor, and sufficient tranquillity for the frailest fishing-boat.

“ There are times when shelter from the wind is scarcely less important than smooth water. In the harbor of Cherburg the in-run of the waves is most effectually arrested by the great mole, and yet nearly every vessel that sought shelter in the gale of 1865 was driven on shore by the wind. Here, again, Boston Harbor claims peculiar advantages, — her moles are promontories and islands rising from twenty to one hundred feet above the sea.”

The protection, preservation, and improvement of harbors and of a coast so important, not only to her own interest, but to the world, are responsibilities which grow more manifest with each experience of the Board. Its attention has been called to almost every section of the coast, and its supervision given to works in every part of it.

The sea-board of Massachusetts northward from Cape Ann is more like that of the Southern States than any part of New England. The immediate shore is a sand beach, with low dunes, behind which are the extensive marshes of Salisbury, Plum Island, Rowley, Ipswich, and Essex, with their numerous creeks and water-spaces. From and including Cape Ann, southward to Cohasset, the shores of Massachusetts Bay are rocky and irregular. Still further southward, along the coast of Scituate, Marshfield, Duxbury, Plymouth, Sandwich, and Barnstable, sand-beaches again characterize the shore, only broken by the cliffs of Scituate and the higher Manomet hills of Plymouth. Beyond Barnstable, the cliffs and drift hills of Cape Cod again change the character of the shore. The same formation marks the shores of Buzzard's Bay, with the exception only of the slightly rocky district in the vicinity of New Bedford; the Elizabeth Islands, Martha's Vineyard, No-Man's Land and Nantucket, having a varied shore of beaches, bluffs, and headlands.



The following statistics show more fully the character of the coast, and give in detail the extent of shore-line as measured by following its irregularities. The distances are stated in miles, — they are close approximations to the actual results of the Coast Survey, and include the shore line of navigable tide-water only : —

From State line to entrance Newburyport Harbor, . . . .	4
Newburyport Harbor and Merrimac River to Chain Bridge, . . .	20
Newburyport Harbor to entrance Plum Island Sound, . . . .	8
Plum Island Sound, Parker River, Rowley River, &c., . . . .	57
Plum Island Sound to entrance Essex River, . . . . .	3
Essex and Ipswich Rivers, . . . . .	25
Essex River to entrance Squam River, . . . . .	2
Squam River, . . . . .	20
Squam River around Cape Ann to Eastern Point, . . . . .	20
Gloucester Harbor, . . . . .	8
Gloucester Harbor to Manchester Harbor, . . . . .	7
Salem Harbor, including Manchester, Beverly, Marblehead, and Islands, . . . . .	50
Marblehead to Point Shirley, including Swampscott and Lynn Har- bors, . . . . .	42
Boston Harbor and tributaries from Point Shirley to Point Aller- ton, . . . . .	150
Islands of Boston Harbor, . . . . .	46
Point Allerton to entrance North River, including Cohasset and Scituate Harbors, . . . . .	31
North and South Rivers, . . . . .	16
North River to entrance Green Harbor River, . . . . .	4
Green Harbor River, . . . . .	9
Green Harbor River to Saquish Head, entrance Plymouth Harbor, .	9
Duxbury Bay, Kingston Bay, and Plymouth Harbor, . . . .	42
Plymouth Harbor to entrance Scusset Creek, . . . . .	19
Scusset Creek, . . . . .	4
Scusset Creek to entrance Sandwich Old Harbor, . . . . .	2
Sandwich Old Harbor and tributaries, . . . . .	8
Sandwich Old Harbor to entrance Scorton Harbor Creek, . . .	3
Scorton Harbor Creek, . . . . .	7
Scorton Harbor Creek to entrance Barnstable Harbor, . . . .	7
Barnstable Harbor, . . . . .	37
Barnstable Harbor to Horse Island, . . . . .	26
Wellfleet Harbor and tributaries, . . . . .	30
Wellfleet Harbor to Race Point, Cape Cod, . . . . .	44
Race Point to entrance Nausett Harbor, . . . . .	30
Nausett Harbor, Town Cove, &c., . . . . .	30
Nausett Harbor to entrance Pleasant Bay, . . . . .	6
Pleasant Bay and branches, . . . . .	34
Pleasant Bay to Chatham Point, . . . . .	4



Monomoy Island and adjoining beaches, . . . . .	24
Old Stage Harbor and interior bays, . . . . .	11
Old Stage Harbor to entrance Bass River, including Herring River	16
Bass River, . . . . .	8
Bass River to Point Gammon, . . . . .	5
Point Gammon to Succonesset, including Lewis Bay, Osterville	
Landing, Cotuit Harbor, and Poponesset Bay, . . . . .	42
Succonesset to Nobska Point, . . . . .	11
Shore ponds between Succonesset and Nobska, . . . . .	35
Naushon and adjoining islands, . . . . .	21
Pasque Island, . . . . .	5
Nashawena Island, . . . . .	9
Cuttyhunk Island, . . . . .	6
Penikese Island, . . . . .	2
Martha's Vineyard, main shore, . . . . .	62
Katama Bay, . . . . .	10
Cape Pogue, Lagoon, Menemsha, and other ponds, . . . . .	71
No-Man's Land, . . . . .	4
Nantucket Island, main shore, . . . . .	50
Nantucket Harbor, . . . . .	18
Tuckernuck Island, . . . . .	8
Muskeget Island, . . . . .	7
Wood's Holl (Nobska Point) to Cohasset Narrows; including bays	
and rivers on east side of Buzzard's Bay, . . . . .	38
Buttermilk Bay, . . . . .	6
Cohasset Narrows to Sconticut Point, including bays and rivers	
on north side of Buzzard's Bay, . . . . .	61
Sconticut Point to Clark's Point (New Bedford Harbor), . . . . .	19
Clark's Point to State line, including bays and rivers, . . . . .	38
Mount Hope Bay and Taunton River, . . . . .	45
	<hr/>
	1,498

The seaboard of Massachusetts is embraced within the parallels of  $41^{\circ} 15'$  north, which passes just tangent to the southern shore of Nantucket and No-Man's Land, and  $42^{\circ} 52'$ , which passes near the boundary-line with New Hampshire. The meridian of  $69^{\circ} 55'$  west passes just tangent to the eastern shore of Cape Cod, near Highland Light, and  $71^{\circ} 07'$  near the boundary with Rhode Island. These limits give a distance of  $97'$  in latitude, and  $72'$  in longitude—a total of 150 geographical miles, within which distance the bays, harbors, and tide-water rivers of the State make up the sum, as given above, of 1,498 miles.

## OFFICE AND FIELD WORK.

The inquiries for information, and the interest manifested in relation to licenses issued and questions connected with them, often involving the definement and adjustment of conflicting rights and privileges, have induced the Board, in consideration of the value the information may be to citizens of the Commonwealth specially interested, and to the public in general, to publish more full statements than formerly of the terms and conditions of the licenses granted, with a description of the nature and extent of the plans approved.

The usual examinations and surveys have been made in all localities where the supervision of the Board required them. In addition to this duty, the work connected with the re-survey of Boston Inner Harbor, which has been in progress during the last season, has called for the constant occupation of the engineers in the field and office.

The following statistics show the details of the work referred to.

*Plans approved by the Board of Harbor Commissioners during the Year 1877, for the Erection of Structures in or over Tide-water, and Licenses granted for such Structures.*

354. George H. Howe, for pile-wharf in Chatham Harbor. Beginning at a point on the southerly side of the bridge across Mitchell's River, distant twenty (20) feet easterly from the easterly side of the draw in said bridge, and running southerly at an angle of  $74\frac{1}{2}^{\circ}$  with said bridge, a distance of seventy-five (75) feet, to a point which is in the alignment of the easterly side of said draw; thence easterly, in a direction parallel to said bridge, to the upland or high-water mark. Approved Feb. 21, 1877.

355. John E. Somes, for extension of wharf on piles in Gloucester Harbor. Beginning at the south-westerly corner of the easterly wharf of John E. Somes, and running southerly in line with the westerly line of the present wharf extended, a distance of thirty-nine (39) feet; thence running southerly again a little more westerly, a distance of ninety-four (94) feet, to a point distant thirty-one (31) feet easterly from the south-easterly corner of the westerly wharf of John E. Somes; thence running easterly, towards the south-westerly corner of the wharf of David G. Allen, a distance of twenty (20) feet; thence running northerly, a distance of one hundred and forty-five (145) feet, to the south-easterly corner of the easterly wharf of John E. Somes. Approved Feb. 28, 1877.

356. Eastern Railroad Company, for additional piles under its bridge

over Charles River. Seven (7) piles in each of the forty-seven (47) old rows from the Prison Point Draw southerly. Approved March 14, 1877.

357. Naumkeag Steam Cotton Company, for solid filling near East Gardner Street, Salem Harbor. Beginning at a point on the high-water mark, at the northerly boundary-line of the flats of the said Company, and running easterly along said boundary-line a distance of three hundred and ninety-two (392) feet; thence southerly, parallel to the westerly line of Derby Wharf, and distant two hundred and fifty (250) feet therefrom, to the southerly boundary-line of said Company's flats; thence westerly, along said southerly boundary-line, to the high-water mark. Approved March 14, 1877.

358. T. A. Newhall, to dredge a channel in Lynn Harbor. Channel to extend due south from the westerly side of his wharf, and to be fifty (50) feet in width. Approved March 21, 1877.

359. Boston and Hingham Steamboat Company, for extension of wharf on piles in the town of Hull. Beginning at the north-westerly corner of the present wharf of said Company, and running southerly at right angles to the northerly line of the present wharf, a distance of fifty-nine (59) feet; thence southerly again,  $15^{\circ}$  more easterly, a distance of sixty-four (64) feet; thence easterly, parallel to the southerly line of the present wharf, a distance of thirty-five (35) feet; thence northerly, at right angles to the last-named line, a distance of sixty-eight (68) feet; thence northerly again,  $44^{\circ}$  more easterly, a distance of thirty-one (31) feet; thence northerly again, parallel to the easterly line of the present wharf, a distance of five (5) feet; thence easterly, parallel to the southerly line of the present wharf, and distant seven (7) feet southerly therefrom, to the upland or high-water mark. Approved April 4, 1877.

360. Boston Land Company, for extension of Atlantic Avenue across Belle Isle Inlet by solid filling, in Boston and Revere. Street to be built fifty (50) feet wide on the surface, sloping thence on each side according to the natural slope of the material; and in building said street said Company may use material excavated from the marsh on each side of said inlet, within the lines of a proposed ditch shown on plan. A culvert shall be built of good, substantial materials, in a strong and workmanlike manner. Approved April 11, 1877.

361. Old Colony Railroad Company, for connecting the northerly draw-pier of its bridge over Fort Point Channel with the northerly draw-pier of the Federal-street Bridge in Boston. The connection shall be made by driving piles in bents or sections of three piles each, which sections shall be placed eight (8) feet apart in the line between said piers. The piles shall be capped and braced, and planked on top, and sheathed on the southerly side. The structure, when completed, shall have a width not exceeding eight (8) feet on top throughout. Approved April 18, 1877.

362. Samuel Knowles, for pile-wharf in Provincetown Harbor. Beginning at a point on the high-water mark in front of his upland, distant eighty-five (85) feet north-easterly from the wharf of S. Nickerson, and running south-easterly in a straight line, which line passes the south-easterly corner of Nickerson's Wharf, a distance of eighty (80) feet

north-easterly therefrom, a distance of two hundred (200) feet; thence running easterly, at right angles to the last-named line, a distance of fifty (50) feet; thence northerly, at right angles to the last-named line, to the upland or high-water mark. Approved May 2, 1877.

363. Jonathan Cook, for pile-wharf near Long Point, Provincetown Harbor. Beginning at a point on the high-water mark, distant four hundred and fifty (450) feet south-westerly from the north-westerly corner of the fort on Long Point, marked A on plan, and running north-westerly at right angles to the general trend of the shore, a distance of seven hundred (700) feet, with a uniform width of thirty (30) feet throughout. For the purpose of strengthening the wharf at the outer end, crib-work filled with stone may be substituted for piling. Approved May 2, 1877.

364. Jonathan Cook, for pile-wharf in Provincetown Harbor. Beginning at a point on the high-water mark, distant about one hundred and three (103) feet more or less westerly from the westerly side of the wharf of H. & S. Cook & Co., which point is also in the westerly boundary-line of the premises of said Jonathan Cook, and running southerly parallel to the wharf of Alfred Cook, a distance of two hundred (200) feet; thence easterly, at right angles to the last-named line, a distance of thirty-five (35) feet; thence northerly, at right angles to the last-named line, to the upland or high-water mark. Approved May 2, 1877.

365. Henry Lyon, for covering with a pile structure the upper portion of the westerly dock of Swett's Wharf, Charlestown District, Boston. Beginning at the north-easterly corner of the present westerly dock, and running southerly along the easterly line of said dock, a distance of fifty-six (56) feet; thence westerly across said dock to the westerly line thereof, at a point distant fifty-six (56) feet southerly from the north-westerly corner of said dock; thence northerly along the westerly line of said dock, a distance of fifty-six (56) feet, to the north-westerly corner of said dock. Approved May 2, 1877.

366. S. A. Holt and the Boston and Lowell Railroad Corporation, for filling a portion of their dock in East Cambridge. Beginning at a point on the south-easterly line of the wharf of S. A. Holt, distant sixty-nine and one-half ( $68\frac{1}{2}$ ) feet north-easterly from the south-westerly corner thereof, and running south-easterly in a straight line across the dock, to the north-westerly line of the wharf of said Corporation, at a point distant thirty-three (33) feet north-easterly from the south-westerly corner thereof. Approved May 2, 1877.

367. Salem and Magnolia Steamboat Company, for solid wharf at Salem Neck, Salem Harbor. Beginning at a point on the high-water mark on Salem Neck, distant one hundred (100) feet north-westerly from a stone wall which is on the dividing line of land belonging to the city of Salem and other parties, and running due north a distance of one hundred and thirty (130) feet; thence easterly, at right angles to the last-named line, a distance of sixty (60) feet; thence northerly again, at right angles to the last-named line, a distance of twenty (20) feet; thence westerly, at right angles to the last named-line, a distance



of ninety-two (92) feet; thence southerly, at right angles to the last-named line, a distance of twenty (20) feet; thence easterly, at right angles to the last-named line, a distance of twenty (20) feet; thence southerly, at right angles to the last named line, a distance of one hundred and thirty (130) feet, more or less, to the high-water mark. Approved May 16, 1877.

368. Malachi Clark, to drive nine (9) piles on the southerly side of Congress-street Bridge, for the support of a water-tank. Express condition that the structure is to be of a temporary character, and that it shall be removed at any time at the request of this Board. Approved May 16, 1877.

369. City of Cambridge, to build a sea-wall on the easterly line of Prison Point Street in Miller's River, between the southerly abutment of Prison Point Bridge, and the sea-wall of the Boston and Lowell Railroad Corporation. Approved May 19, 1877.

370. Edward P. Haskell, for filling the dock lying between his wharf and the New Bedford and Fairhaven Bridge, New Bedford. Beginning at the north-easterly corner of the present wharf, and running northerly in line with the easterly line of the present wharf extended, to the southerly line of the bridge running from New Bedford to Fairhaven; thence running westerly along said southerly line of said bridge to the upper end of said northerly dock of Edward P. Haskell. Approved May 23, 1877.

371. Boston, Winthrop, and Point Shirley Railroad Company, for solid filling on the line of its road in Winthrop, for a distance of two hundred and seventy-five (275) feet; an opening or culvert, eighteen (18) inches square, to be left under said road for the purpose of drainage. Approved June 6, 1877.

372. James O. Young, for an iron pier on Revere Beach, Revere. Beginning at a point on the beach or high-water mark, distant two hundred (200) feet southerly from the Pavilion Hotel on said Revere Beach, and running easterly at right angles to said beach, a distance of one thousand (1,000) feet, with a general width of ten (10) feet, and a T at the end, fifty (50) feet by twenty (20) feet, as shown on plan. Approved June 7, 1877.

373. M. W. Haskins & Brother, for pile-wharf in front of their premises on Maverick Street, foot of Jeffries Street, East Boston. Beginning on the westerly boundary-line of the premises of M. W. Haskins & Brother, at a point distant on said boundary-line, one hundred and fifteen (115) feet from the northerly line of Maverick Street, and running north-easterly, along said boundary-line, a distance of fifty (50) feet; thence south-easterly, at right angles to the last described line, a distance of thirty-five (35) feet; thence south-westerly, at right angles to the last described line, a distance of fifty (50) feet; thence north-westerly, a distance of thirty-five (35) feet, to the point of beginning. Approved June 13, 1877.

374. City of Boston, to rebuild that portion of Chelsea Bridge, which said city is to support under chapter 106, Acts of 1876. The portion of the present bridge, between the Charlestown shore and the harbor line, and the portion between the two sea-walls, built by the Mystic River



Corporation, shall be filled solid, sixty-six (66) feet in width, with suitable abutment walls, as shown on the plans. The portion of the bridge crossing the "South Channel" of Mystic River, and connecting the above mentioned portions, shall be a wooden pile-bridge, fifty (50) feet wide, provided with an opening forty (40) feet wide in the clear, for the passage of vessels, and with an iron turn-table draw or swing bridge, carried on a pile foundation. Suitable draw-piers to facilitate the passage of vessels, fenders for the protection of the bridge, quarters for the draw-tender, and support for the water-mains, shall be provided, all as shown on the plans.

The portion of the bridge supported by the city of Boston, northerly of the northerly wall of the Mystic River Corporation Wharf, shall be a pile-bridge thirty-two (32) feet wide, as shown on plans. Approved June 22, 1877.

375. Menauhant Land and Wharf Company, for a pile-wharf at Menauhant, Falmouth. Beginning at a point on high-water mark, distant six (6) feet easterly from the intersection of the westerly line of Central Avenue with said high-water mark, and running S. 9° W. a distance of one hundred and twenty (120) feet; thence easterly, at right angles to the last-named line, a distance of thirty-two (32) feet; thence south-easterly, making an angle of 45° with the last-named line, a distance of one hundred (100) feet; thence north-easterly, at right angles to the last-named line, a distance of fifteen (15) feet; thence north-westerly, at right angles to the last-named line, a distance of one hundred (100) feet; thence northerly, making an angle of 45° with the last-named line, a distance of twelve (12) feet; thence westerly, at right angles to the last-named line, a distance of twenty (20) feet; thence northerly again, at right angles to the last-named line to a point on the high-water mark, distant twenty (20) feet easterly from the point of beginning. Approved June 22, 1878.

376. City of Gloucester, to dredge flats in front of the Ferry Landing at East Gloucester, within a radius of forty (40) feet from the end of the present Ferry Landing, provided the material shall be deposited in a locality where it will not be washed away to the injury of the channels in Gloucester Harbor. Approved June 22, 1877.

377. Old Colony Railroad Company, to drive a row of piles along its sea-wall in Fort Point Channel between Broadway and Dover-street bridges, Boston, for the purpose of strengthening said wall and also for the safety of vessels; provided the piles shall be driven perpendicular, and shall not extend beyond the line of the present structure, at the plane of mean low water. Approved June 29, 1877.

378. Lynn and Boston Horse Railroad Company, for temporary bridge across Mystic River, as authorized by Chapter 106, Acts of 1876.

*First:* Beginning at a point on the westerly line of Chelsea Bridge, about three hundred and twenty (320) feet northerly from the northerly wall of the Mystic Improvement Company's Wharf, crossing said wall at a point distant about eighty (80) feet westerly from Chelsea Bridge, and continuing in the same general direction to the solid filling of the Boston and Lowell Railroad Company where the bridge will stop and the track

continue by a curve over said filling to a point distant about three hundred and eighty (380) feet from the centre line of Chelsea Bridge; where another bridge will be constructed running across the South Channel of Mystic River to a point in the wall of the Oriental Oil Company's Wharf, distant about one hundred and seventy (170) feet from the said centre line.

*Second:* The alternative plan commences at a point on the westerly line of Chelsea Bridge, distant about three hundred and ten (310) feet northerly from the northerly wall of the Mystic Improvement Company's Wharf, and runs to a point in said wall one hundred and twenty-five (125) feet from said bridge, the new bridge running on a curved line for fifty (50) feet of its length, before reaching said wall, and continuing on a curve and tangent until the filling on said Mystic Improvement Company's flats is reached; thence over said filling, or by their present track on Chelsea Bridge, to the Boston and Lowell Railroad Company's Wharf, and over said wharf to the aforesaid line of a temporary bridge over the South Channel of Mystic River.

The above measurements are on the centre line of the proposed bridge.

In the bridge over the South Channel, a draw-line shall be constructed of the counter-balance leaf pattern, with a clear opening of thirty-four (34) feet, for the passage of vessels, as shown on plan. Approved July 19, 1877.

378c. Lynn and Boston Horse Railroad Company, to modify the manner of crossing South Channel of Mystic River, by curving from the draw to the Boston and Lowell Railroad filling southerly from the location fixed in No. 378. Approved Aug. 8, 1877.

379. Augustus H. Wonson, to build a solid wharf in Gloucester Harbor. Beginning at a point on the high ledge marked I on plan, and running northerly towards the harbor line, a distance of forty-seven (47) feet, to a point marked J on plan; thence westerly, at right angles to the last-named line, and parallel with the harbor line, a distance of sixty (60) feet, to a point marked K on plan; thence south-westerly, in a straight line, a distance of eighty-eight (88) feet, to a point on the high ledge, marked L on plan, which point is distant one hundred and one (101) feet south-westerly from the point of beginning. Permission is also granted to said Wonson to build a causeway extending from the main land at Rocky Neck, across to the high ledge, of a uniform width of twenty (20) feet, as shown on said plan. Approved July 25, 1877.

380. Trustees under the will of John W. Trull, to fill solid a part of the dock in front of their premises, adjoining Warren Bridge, Boston. Beginning at a point on the westerly side of the dock in Trull's Wharf, distant one hundred (100) feet north-westerly from the south-westerly corner of said dock, and running north-easterly at right angles to the said westerly line of said dock, a distance of about eighty (80) feet, to the solid filling of Minot's Wharf. Approved Aug. 1, 1877.

381. Selectmen of Scituate, for the consent of the Board to removal of material from beaches of Scituate, under chapter 196, Acts of 1877. Consent given to said selectmen and other inhabitants of said town, for the removal of material from the beaches of said town under the provisions of said chapter, from the following localities, namely: —

From the beach between high and low water marks, westwardly from Hazzard's Rocks, a distance not exceeding five hundred (500) feet. From the beach between high and low water marks, from the terminus of the highway leading to North Scituate northwardly, a distance not exceeding three hundred (300) feet, or to the bulkhead. From the inner side of the shingle beach opposite Man Hill. This consent is not to be construed to impair the rights of the owners of the beaches upon which said material is located. Approved July 26, 1877.

382. City of Boston, to rebuild the draw-pier of Mount Washington Avenue Bridge. The draw-pier to be strengthened by driving additional piles in such number and position as are shown by circles colored red on plan. New sheathing to be substituted for old on each side of the pier, and new bracing substituted for old wherever necessary for the safety of draw and pier. Approved Aug. 1, 1877.

383. Plymouth Cordage Company, to extend wharf in Plymouth Harbor. Beginning at the north-easterly corner of the present wharf, and running north-easterly in line with the easterly side of the present wharf extended, a distance of ninety (90) feet; thence north-westerly, at right angles to the last-named line, a distance of thirty (30) feet; thence south-westerly, at right angles to the last-named line, to the north-westerly corner of the present wharf. Approved Aug. 8, 1877.

384. Maverick Oil Company, to extend its wharf on piles in Chelsea Creek, East Boston. Beginning at the north-easterly corner of the present wharf, and running northerly in line with the easterly side of the present wharf extended, a distance of one hundred and eighty-two (182) feet; thence westerly, at right angles to the last-named line, a distance of about fifty (50) feet, to the easterly boundary-line of the East Boston Gas Light Company's premises; thence southerly, along said boundary-line, to the north-easterly corner of the wharf of the East Boston Gas Light Company. Approved Aug. 15, 1877.

385. G. W. W. Dove and others, to build a wharf on the southerly side of Wood's Holl Harbor, partly solid and partly on piles. Beginning at a point on the high-water line on the southerly side of Wood's Holl Harbor, distant about four hundred and eighty-two (482) feet westerly from the westerly side of the Pacific Guano Company's Wharf, and running southerly, at right angles to the general trend of the shore, a distance of sixty (60) feet; thence westerly, at right angles to the last-named line, a distance of sixty (60) feet; thence northerly, at right angles to the last-named line to the high-water line. In front of the above described solid structure a platform may be constructed on piles, not to exceed ten (10) feet in width and sixty (60) feet in length, as shown on said plan. Approved Aug. 15, 1877.

386. George O. Shattuck, to build a solid wharf in Mattapoisett Harbor. Beginning at a point on the high-water mark on the easterly side of Mattapoisett Harbor, distant about nine hundred and five (905) feet northerly from the northerly boundary-line of land belonging to the United States Government at Ned's Point, and running S. 70½° W., a distance of one hundred and thirty (130) feet, with a uniform width of seventeen (17) feet to low-water mark. Approved Aug. 15, 1877.



387. George J. Tarr, to build a solid wharf in front of his premises in Gloucester Harbor at Fort Point. Beginning at the north-westerly corner of the premises of said George J. Tarr, at a bolt, and running south-easterly, a distance of eighty (80) feet, to a drill-hole in a ledge; thence S.  $50^{\circ}$  W., a distance of thirty-five (35) feet, to a bolt in a ledge near high-water line, marked B on plan; thence S.  $60^{\circ}$  E., and parallel with the stone wharf of Lucy D. Rogers, a distance of seventeen (17) feet, to a point marked C on plan; thence S.  $51^{\circ}$  W., a distance of one hundred and twenty-six (126) feet, to a point marked D on said plan; thence S.  $16^{\circ}$   $20'$  E., a distance of twenty-two (22) feet, to a point marked E on plan; thence S.  $39^{\circ}$  W., a distance of thirty-five (35) feet, to a point marked F on plan; thence N.  $37^{\circ}$   $40'$  W., a distance of one hundred and twenty-two (122) feet, to a point marked G on plan; thence N.  $50^{\circ}$   $20'$  E., a distance of one hundred and two (102) feet, to a point marked H on plan, near high-water line; thence on the last mentioned course a distance of eighty-four (84) feet, to the point of beginning. Approved Aug. 18, 1877.

388. Pacific Guano Company, to extend a solid wharf in Wood's Holl Harbor. Beginning at a point on the westerly side of the present wharf, distant sixty-five (65) feet northerly from the south-westerly corner of said present wharf, and running westerly, at right angles to the westerly side of the present wharf, a distance of one hundred and ten (110) feet; thence northerly, at right angles to the last-named line, a distance of two hundred and fifty (250) feet, to the high-water mark. Approved Aug. 22, 1877.

389. William H. Quiner, to extend his wharf, partly solid and partly on piles, in Beverly Harbor. Beginning at the most south-easterly corner of the present wharf, and running southerly in line with the most easterly line of the present wharf extended, a distance of about ninety-three (93) feet; thence westerly, in line with the southerly end of the present wharf extended, a distance of about fifty (50) feet, to the present wharf. In front of the afore described and present solid structure, a pile structure may be built, not exceeding thirty-five (35) feet in width, within the easterly and westerly lines of the present wharf extended. Approved Aug. 22, 1877.

390. Nathan B. Goodnow and C. A. Ransom, to maintain a floating wharf in Back Bay, between Sagamore Hill and White Head in the town of Hull. Beginning at a point on the high-water mark, on the northerly side of Sagamore Hill, distant one hundred and eighty-eight (188) feet easterly from the boundary-line between land of said C. A. Ransom and land of Starkes Whiton, Trustee, and running N.  $50^{\circ}$  W., a distance of three hundred and fifty (350) feet, with a uniform width of four (4) feet throughout. Approved Aug. 31, 1877.

391. Eastern Railroad Company, to fill solid two parcels of flats in Prison Point Bay, Boston:—

*First.* Beginning at a point in the boundary-line as established between flats of the Eastern Railroad Company and of the Boston and Maine Railroad Company, and at the southerly or outer side of the old mill-dam, marked A on plan, and running in a south-easterly direction by said boundary-line, a distance of about one thousand and eighty-five (1,085)

feet, to the flats of the city of Boston marked E on plan; thence north-easterly, by said flats of the city of Boston, a distance of about seven hundred and thirty (730) feet, to Canal Street, marked D on plan; thence north-westerly, by Canal Street, a distance of three hundred and twenty-two (322) feet, to the old mill wharf and dam marked C on plan; thence on various courses, by the southerly side of said mill wharf and dam, to the point of beginning. Said first parcel containing about ten and  $\frac{4.5}{100}$  (10.45) acres.

*Second.* Beginning at a point in the boundary-line between flats of the Eastern Railroad Company and of the Boston and Maine Railroad Company, and at flats of the city of Boston marked F on plan, and running in a south-easterly direction by said boundary-line, a distance of about five hundred and sixty-six (566) feet, to flats of the Commonwealth marked N on plan; thence north-easterly, by said flats and land of the Commonwealth, a distance of about six hundred and seventy-five (675) feet, to Canal Street, marked M on plan; thence north-westerly, by Canal Street, a distance of two hundred and five and  $\frac{7.0}{100}$  (205.70) feet, to a point marked L on plan; thence south-westerly, by land of parties unknown, a distance of three hundred (300) feet, to a point marked K on plan; thence north-westerly, by land of said parties unknown, a distance of two hundred and ninety-four and  $\frac{7.7}{100}$  (294.77) feet, to a point marked I on plan; thence north-easterly, by land of said parties unknown, a distance of three hundred (300) feet, to Canal Street, marked H on plan; thence north-westerly, by Canal Street, a distance of one hundred and fifty-five and  $\frac{5.6}{100}$  feet, to land of the city of Boston marked G on plan; thence south-westerly, by land of said city of Boston, a distance of about seven hundred and thirty (730) feet, to the point of beginning. Said second parcel containing about seven and  $\frac{6.3}{100}$  (7.63) acres. Approved Sept. 5, 1877.

392. City of Boston, to rebuild that portion of Neponset Bridge lying within its limits. The said bridge shall be rebuilt in the form and of the dimensions as shown on the plan, being substantially in its present position. The draw-piers shall be lengthened to one hundred and sixty-five (165) feet on each side of the bridge. The draw-way, or opening, for vessels to pass shall be increased in width, from twenty-nine and  $\frac{1}{2}$  (29.5) feet to thirty-two (32) feet. The draw shall be an iron leaf-draw, twenty-five feet wide. All the piles marked on plan by circles shaded black and blue shall be drawn up, and those marked by circles shaded red shall be driven. Approved Sept. 12, 1877.

393. Town of Brookline, to extend its main sewer to the harbor-line in Charles River. Beginning at a point on the northerly line of Brighton Avenue, opposite the centre line of St. Mary's Street, and running north-easterly in line with the centre line of St. Mary's Street extended, to the harbor-line. The sewer to be built of brick masonry, protected by walls formed by piles and sheet-piling, and covered with earth. Approved Sept. 19, 1877.

394. Ellen A. Bealkey, to build a wharf and two sets of marine-railways in Mount Hope Bay, Somerset. The wharf begins at a point on the high-water mark, in front of her upland on the westerly shore of



Taunton River, and about twenty-one hundred and sixty-five (2,165) feet southerly from the bridge across Taunton River, connecting Somerset and Fall River, and runs south-easterly, at right angles to the general trend of the shore, a distance of five hundred (500) feet, with a uniform width of twenty-five (25) feet. That part of the wharf which lies between high and low water marks may be built solid, but the rest on piles. The railway structures shall be built on piles, thirty-five (35) feet wide, parallel to said wharf, and forty (40) feet apart, as shown on plan. Approved Sept. 19, 1877.

395. Philadelphia and Reading Coal and Iron Company, to dredge a channel in front of its wharf in New Bedford Harbor. Beginning at the north corner of the present wharf, and running easterly, in a straight line until it connects with the main channel dredged by the General Government. The southern boundary of the channel to be parallel to the above described line, and distant one hundred and twenty-five (125) feet southerly therefrom. Said channel to continue up the dock on the southerly side of the present wharf, to a width of sixty (60) feet, and to depth of eighteen (18) feet at mean high water. The material dredged in said channel shall be deposited in such places as this Board shall direct. Approved Oct. 10, 1877.

396. Heirs of John Sparhawk, to build a pile wharf at Naugus Head, in the town of Marblehead. Beginning at a point on the westerly side of Naugus Head, at high-water mark, distant one hundred and fifty (150) feet northerly from a stone wall, and running westerly nearly at right angles to the general trend of the shore, a distance of one hundred and fifty (150) feet; thence northerly, at right angles to the last-named line, a distance of fifty (50) feet; thence easterly, at right angles to the last-named line, to the upland or high-water mark. Approved Oct. 17, 1877.

397. City of Chelsea, to fill solid a portion of Chelsea Bridge under authority of chapter 106, Acts of 1876. Beginning at the south-westerly end of the present abutment of Chelsea Bridge, and running southerly along the westerly line of said bridge, a distance of two hundred and fifty (250) feet; thence easterly, at right angles to the last-named line, a distance of sixty-six (66) feet; thence northerly, at right angles to the last-named line, to the south-westerly corner of the wall of Black's Wharf. Approved Nov. 20, 1877.

398. Boston and Albany Railroad Company, to widen Pier No. 5, of the Grand Junction Wharves at East Boston, and also to deepen its Dock No. 5 to eighteen (18) feet at mean low water. Beginning at a point on the northerly end of Dock No. 5, distant twenty-seven (27) feet westerly from the face-line of the brick wall of the elevator, and running south-easterly, parallel to said face-line of brick wall, to an angle in the westerly line at Pier No. 5; thence southerly, parallel to the westerly line of Pier No. 5, to a point in the southerly line of Pier No. 5 extended; thence south-easterly, along said southerly line of Pier No. 5 extended, to the south-westerly corner of Pier No. 5. The said Company is further authorized to deepen its Dock No. 5 to a depth of eighteen (18) feet at mean low water, by dredging; and the material so dredged shall be de-

posited at such places as this Board shall direct. Approved Nov. 21, 1877.

399. Boston and Albany Railroad Company, to cover the whole of Dock No. 2, Grand Junction Wharves at East Boston with a pile structure Beginning at the south-easterly corner of Pier No. 1, and running south-easterly in a straight line to the north-westerly corner of Pier No. 2. The space lying northerly of the above described line and between said piers may be covered as shown on plan. Approved Nov. 28, 1877.

401. Swett & Co., to widen and extend wharf in Harbor Cove, Gloucester Harbor, on piles. Beginning at the north-easterly corner of the present wharf of Swett & Co., and running easterly a distance of forty (40) feet, to a point in the Harbor Commissioners' line, which point is seven (7) feet northerly from the northerly line of the present wharf of Swett & Co. extended; thence running southerly, along said harbor line, a distance of thirty-one (31) feet, to an angle in said harbor line, and continuing in the same course southerly for a distance of nine (9) feet; thence westerly a distance of one hundred and fifty-three (153) feet, to a point twenty-six (26) feet northerly from the northerly line of Maddock's Wharf; thence southerly, at right angles to the last-named line, to Maddock's Wharf. Approved Dec. 5, 1877.

402. Boston and Lowell Railroad Corporation, to fill two parcels of flats situated on the easterly and westerly sides of Austin Street, East Cambridge. The parcel situated on the easterly side of Austin Street shall include all the unfilled space inside of the sea-wall of the Boston and Lowell Railroad Corporation, said space being marked by the letter A on plan. The parcel situated on the westerly side of Austin Street shall be defined by the following described lines: Beginning at a point on the north-easterly line of the sea-wall or wharf of the Boston and Lowell Railroad Corporation in Miller's River, ten (10) feet south-easterly from the north-westerly corner thereof, and running north-easterly, parallel to the westerly line of said sea-wall or wharf, a distance of about five hundred (500) feet; thence south-easterly, a distance of about three hundred and ninety (390) feet, to the westerly side of Austin Street, in such a direction that if the said line were continued across Austin Street, it would connect with the sea-wall of the said Railroad Corporation on the easterly side of said street; said parcel being marked by the letter B on plan.

Said filling shall be enclosed by suitable bulkheads or sea-walls, as the said Corporation may elect. Approved Dec. 12, 1877.

403. Selectmen of the town of Milton, to repair and lengthen the draw-pier in Granite Bridge across Neponset River. The easterly draw-pier in said Granite Bridge may be lengthened for a distance of fifteen (15) feet. The additional piles which are necessary in repairing said draw-pier shall be driven in such number and such position as are shown by circles in red ink on said plan. Approved Dec. 12, 1877.

404. Proprietors of Rowe's Wharf, to rebuild certain portions of the wharf, on the northerly side, in Fort Point Channel, Boston. The portion to be rebuilt begins at the most north-westerly corner on the north-

erly side of the present wharf, marked A on plan, and runs easterly in the extension of the northerly side of the present wharf, a distance of forty-three (43) feet; thence running southerly, nearly at right angles to the last-named line, to the most north-westerly, corner of the sea-wall on the northerly side of said Rowe's Wharf, marked B on plan. The portion lying northerly of the following described line shall be taken up: Beginning at a point on the easterly line of said sea-wall marked C on plan, distant seven (7) feet southerly from the point marked B on plan, and running easterly, parallel to the northerly line of the present wharf, to an angle in the present wharf, marked D on plan. The piles shall be driven in such number and position as are shown by circles shaded red on said plan. Approved Dec. 19, 1877.

405. City of Gloucester, to fill a portion of its flats adjoining Commercial Street. Beginning at a point on the northerly side of the wharf of Swett & Co., distant sixty-eight (68) feet easterly from the easterly side of Commercial Street, measuring along the northerly side of said wharf, and running northerly at right angles to said northerly side of said wharf, a distance of fifty-six (56) feet more or less, to the southerly side of the wharf of Patrick Coffee. Approved December 31, 1877.

### *Hearings before the Board in Addition to the regular Business Meetings.*

Four hearings with Charles H. Lewis and Boynton Brothers, for payments on account of dredging off Battery Wharf.

Two hearings with a committee of the town of Winthrop in regard to the probable effect of the sewage of the city of Boston, proposed to enter Boston Harbor at "Shirley Gut."

One hearing with Capt. J. Leary, in relation to unreasonable delay at the railroad-draws on Charles River.

Three hearings on the petition of Messrs Smith & Douglass for leave to place a fish-weir on the N. N. W. side of Great Misery Island, Salem Harbor.

One hearing on complaint of John Foster in regard to injury to his wharf by a sewer of the city of Boston, in Neponset River.

One hearing on the petition of John E. Somes for leave to extend his wharf in Gloucester Harbor.

One hearing on the petition of the Naumkeag Steam Cotton Company for leave to build a granite wall, and fill flats in Salem Harbor.

One hearing on the petition of F. A. Newhall, for leave to dredge a channel in Lynn Harbor.

One hearing on the petition of the Boston and Hingham Steamboat Company, for leave to enlarge its wharf at Hull.

One hearing on the petition of the Old Colony Railroad Company for leave to connect its draw-pier with that of Federal Street Bridge, in Fort Point Channel, by a pier eight feet in width.

• One hearing on the petition of the Boston Land Company, for leave to extend a street over its flats at Breed's Island.

One hearing with the agents of the several foreign steamship lines in relation to dredging operations in Boston Harbor, for the season of 1877.



One hearing on the petition of S. A. Holt and the Boston and Lowell Railroad Corporation for leave to fill flats in Miller's River.

One hearing on the petition of the Old Colony Railroad Company in regard to the location of the boat-house of the Shawmut Boat Club, on the easterly side of Dover Street Bridge.

One hearing on the petition of Henry Lyon for leave to cover with a pile structure the upper portion of the westerly dock of Swett's Wharf, in Charles River, Charlestown District.

One hearing on the petition of John P. Squire and others, wharf owners at the upper end of Miller's River, representing that the filling done by the Boston and Lowell Railroad Corporation at its bridge over Miller's River is washing into the said river to the injury of their property, and that said Corporation should be held responsible for such injury.

One hearing on the petition of the Salem and Magnolia Steamboat Company for leave to build a solid wharf on "Salem Neck," Salem Harbor.

Two hearings on the petition of the Eastern Railroad Company for leave to fill its flats in Prison Point Bay, Charlestown District.

Two hearings on the petition of Abraham H. Tower for leave to take gravel from "Bassing Beach," Cohasset Harbor.

One hearing on the petition of the Boston, Winthrop, and Point Shirley Railroad Company for leave to fill flats on the line of its road in Winthrop.

One hearing on the petition of the Shawmut Boat Club for leave to moor a floating boat-house at Dover Street Bridge.

Two hearings on the petition of the South Cove Corporation and George W. Tuxbury for leave to fill flats in South Bay.

Four hearings on the petition of the Lynn and Boston Railroad Company for leave to build temporary bridges across Mystic River.

One hearing on the petition of John T. Heard, for the Trustees under the will of John W. Trull, for leave to fill solid a portion of the dock adjoining property on Causeway Street, Charles River, now leased to Loyal Lovejoy & Company.

One hearing on the petition of Augustus H. Wonson for leave to build solid a part of his wharf on "Rocky Neck," Gloucester Harbor.

One hearing on the petition of George J. Tarr for leave to build a wharf in Gloucester Harbor.

One hearing on the petition of the Maverick Oil Company for leave to extend its wharf in Chelsea Creek, East Boston.

One hearing on the petition of W. H. Quiner for leave to extend his wharf in Beverly Harbor.

One hearing on the petition of Nathan B. Goodnow for leave to maintain a floating wharf at Nantasket, near Sagamore Head.

One hearing on the petition of Ellen A. Bealkey for leave to build a wharf and two marine railways in Taunton River at Somerset, opposite Fall River.

One hearing on the petition of the town of Brookline for leave to extend a sewer into Charles River opposite St. Mary's Street.

Two hearings on the petition of the Boston and Albany Railroad Company for leave to occupy dock room in Grand Junction Wharves, East Boston.



Two hearings on the petition of Henry Breed for leave to fill flats in Lynn Harbor.

Three conferences with the Board of Land Commissioners in regard to matters in connection with the South Boston Flats.

Two hearings with Boston, Revere Beach, and Lynn Railroad Company in relation to payment for Commonwealth's flats taken by their wharf structures in Boston and East Boston.

One hearing on the petition of the Philadelphia and Reading Coal and Iron Company for leave to dredge a channel from its wharf in New Bedford to connect with the channel dredged by the United States Government.

Two hearings in regard to a change in the harbor line on the northerly side of Charles River, near Brookline Bridge, in accordance to chapter 37, Resolves of 1877.

Two conferences with the Committee on Streets of the City of Boston in regard to the extension of B Street to Eastern Avenue, South Boston Flats.

One hearing on the petition of Swett & Co. for leave to extend their wharf in Gloucester Harbor.

One hearing on the petition of the City of Chelsea for leave to build solid a portion of Chelsea Bridge under chapter 106, Acts of 1876.

Two hearings on the petition of the Boston and Lowell Railroad Corporation for leave to widen its freight bridge across Charles River.

One hearing with Capt. F. C. Cates, harbor-master of the port of Boston, and a committee of the Boston Tow-Boat Association, in relation to the dumping of ashes in Boston Harbor.

Two hearings on the petition of the selectmen of the town of Scituate for leave to take gravel from Scituate beaches between the first and second cliffs.

Two conferences with J. W. Gerard and A. D. Williams in regard to changing the harbor line in South Bay.

Three hearings on the petition of the New York and New England Railroad Company for leave to widen its terminal facilities in Fort Point Channel on the Boston side.

One hearing on the petition of the selectmen of the town of Milton for leave to repair and lengthen the draw-pier in Granite Bridge, Neponset River.

### *Field Surveys.*

Survey in Chatham Harbor for the purpose of wharf extension by George H. Howe of Chatham, and plans made thereof.

Two surveys in front of the National Dock and Warehouse Company's Wharves, East Boston, for the purpose of ascertaining the amount of material dredged under contract with the Harbor Improvement Company, and plans made thereof.

Survey in front of Grand Junction and Cunard wharves, East Boston, for the purpose of ascertaining the amount of material to be removed by dredging, and inviting proposals for such dredging, and plans made thereof.

Survey of Bassing Beach and surrounding channel, Cohasset Harbor, for the purpose of ascertaining whether the removal of sand and gravel from said beach is injurious to the navigation of Cohasset Harbor, and plan made thereof.

Two surveys of Battery Wharf Shoal, the removal of which was under contract with Charles H. Lewis, for the purpose of ascertaining the amount of material dredged in completion of the contract, and plans made thereof.

Two surveys off Cunard Wharf, East Boston, for the purpose of ascertaining amount of material dredged under contract with the Harbor Improvement Company, and plans made thereof.

Three surveys off Pier 6, Grand Junction wharves, East Boston, for the purpose of ascertaining the amount of material dredged under contract with W. S. Fretch & Co., and plans made thereof.

Survey of flats filled by S. A. Holt and the Boston and Lowell Railroad Corporation in East Cambridge.

Survey of the Boston and Lowell Railroad Corporation's ground in East Cambridge, as petitioned for by them to be filled, for the purpose of assessing compensation for tide-water displaced by such filling.

Survey of the Bass and Gurnet Rocks, at the entrance of Plymouth Harbor, off Gurnet Head, for the purpose of petitioning the General Government for their removal, according to chapter 12 of the Resolves of 1877, and plans made thereof.

Survey of Prison Point Bay and adjacent basins, for the purpose of ascertaining the amount of compensation for tide-water displaced that could be had by filling said bay and basins up to the height of high-water mark.

Survey of flats in Miller's River, for the purpose of ascertaining how much of these flats can be allowed as compensation in kind above the plane of mean low-water.

Surveys made of all structures in tide-water in Poston Harbor wherever compensation for tide-water displaced is assessed.

Each year's work by the Board, though unattended by striking or special features, adds to the provision for preserving and improving the harbors of the Commonwealth. To the labors of those who have preceded the present Board the usefulness of the latter is largely due; and the greatest utility of present work demands that it shall be so conducted that those who follow shall work with wider knowledge and larger means. The Board continues much indebted to the distinguished scientific men of the United States Advisory Council and of the Coast Survey, whose assistance it has enjoyed. The routine work of the Board is continually increasing in its demand upon the time of the members; but it is gratifying to know, that, notwithstanding the extreme

depression of business, so long continued, there is a constant demand for further facilities for navigation in the principal ports. Nearly every railroad having a terminus in Boston has been an applicant during the year for permission to occupy tide-water to enlarge accommodation for existing business.

FREDERIC W. LINCOLN.  
FRANCIS A. NYE.  
ALBERT MASON.

Boston, January, 1878.





## DEATH OF ADMIRAL DAVIS.

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At a meeting of the Board of Harbor Commissioners held at their office, Feb. 21, 1877, the following resolutions were adopted on hearing of the death at Washington, Feb. 18, of Rear-Admiral Davis, a member of their Advisory Council: —

*Resolved*, That the Board of Harbor Commissioners learned with deep regret the death of Admiral Charles Henry Davis. He has been during the last ten years a member of its Advisory Council, and has aided by his counsel and influence, and by his eminent scientific attainments as a physical hydrographer, the great improvements that have been made during that time on the harbors and the coast of his State.

*Resolved*, That the members, as individuals, regret that they will be no more associated with one who by his courage, his accomplishments, and manners, formed the ideal of a soldier, a scholar, and a gentleman.

*Voted*, That a copy of the above resolutions be transmitted by the chairman to the family of the deceased.

Admiral Davis was born in Boston, Jan. 10, 1807. He received his education in his native town, graduating from the Latin School, and entered Harvard College in 1821. After leaving that institution, he was appointed a midshipman in the United States Navy, and was connected with that service in the several grades of professional rank, until his decease. In 1842 he was detailed for duty in the United States Coast Survey. He remained in this department for a number of years under Mr. Hassler and his successor, Professor Bache. During this time he commenced those investigations into the laws of engineering in tidal harbors, the fruits of which were shown from time to time in the numerous memoirs and reports which he wrote on the great harbors of the United States and kindred subjects. Naturally

he took a great interest in the study of the harbor of his native city. In 1851 he read to the American Academy of Arts and Sciences an important paper on its character, tracing its changes from colonial times, with suggestions as to its dangers and the methods for its improvement. This valuable paper is printed in the fifth volume of its transactions.

In 1859 he was invited by the city government, in connection with Gen. J. G. Totten, Chief Engineer of the United States Army, and Professor A. D. Bache, Superintendent of United States Coast Survey, to constitute a Board of Commissioners for the examination of the waters of Boston Bay. Professor Henry Mitchell was afterwards added to this commission. Extensive and exhaustive surveys were made for a number of years under their direction; and the series of their reports published by the city have obtained a high reputation, not only for the local information they contain, but for the general principles of science which are discussed and established for the safety and care of all other harbors and tidal waters. On the organization of the Massachusetts Board of Harbor Commissioners, the United States Commission was invited to act as their Advisory Council. They accepted the trust, without any promise of pecuniary value, but as a matter of public spirit; and their labors have been of eminent service to the Commonwealth, but, on account of locality and personal knowledge, Admiral Davis's share has been more prominent than his early colleagues.

In all the relations of life Admiral Davis was a true son of Massachusetts. He was proud of his native State, and sought by his own career in science and arms to add to its fame and reputation. In the war of the Rebellion his gallant services were recognized by votes of thanks by Congress and by the Legislature of our own Commonwealth.

His interest in the Board and in the service to which it is devoted, and the feeling that this community has met with a loss by his death, induce us to embrace the occasion which our Annual Report furnishes to add this brief tribute to his memory.

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APPENDIX.

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[A.]

## IMPROVEMENT OF SOUTH BOSTON FLATS.

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REPORT OF THE ENGINEER IN CHARGE, DEC. 31, 1877.

THE past year has enabled the contractors, Messrs. Clapp & Ballou, to complete the work of building the walls, and filling the 25 acres of flats undertaken in the contracts of Sept. 29, 1873, and June 30, 1875.<sup>1</sup>

Although the progress of the work has been from time to time described in former reports, this may be a proper time to give a summary description of the whole work and its progress, with the reasons for adopting the existing forms of the structures and the materials actually used.

Beginning on the east side of Fort Point Channel, at the northern boundary of the lands of the Boston Wharf Company, we have a light sea-wall along the easterly side of this channel, built upon piles, for a length of about 720 feet. A section of this wall is shown on the middle of plate F, figure 3. The piles are capped with a grillage of three-inch spruce plank in both directions, at a level of  $1\frac{8}{10}$  feet below mean low water, where the wall is founded, nine feet in thickness. It is built to the level of 16 feet above mean low water, and is therefore  $17\frac{3}{10}$  feet in height above the plank. At the bottom of the coping course it is five feet thick, having a batter of about two inches to the foot on the face. The coping is set back about a foot from the face, to give a bearing for the platform which is intended to bridge the interval between the face of the wall and the harbor-line, (28 feet) by means of which interval a depth of water of some 12 to 18 feet is had along the harbor-line at low water, without exposing the piles to the water. These piles were driven from 20 to 30 feet into the bottom, some ten feet of which was a stiff material, affording good foundation for bearing loads; but the top is too soft to give much lateral support. The piles are in five rows, about two feet apart, centre to

<sup>1</sup> See appendices of the eighth and tenth annual reports.

centre, across the wall, and two and a half feet apart on centres, lengthwise. The mud was removed for about two feet below their heads, and this space was filled with oyster-shells, well packed. The wall is of dry rubble granite masonry, and is ballasted in the rear with large and small broken stone and oyster-shells, the ballast assuming its own slope from a point two feet back of the wall at the top.

The bottom of Fort Point Channel has been dredged outside the harbor-line to a depth of 12 feet at low water down to the line of Oliver Street extended, thence sloping down to a depth of about 19 feet at the north end of this light wall. Greater depth than this could not be safely maintained along the front of a wall of this class, without giving more width for a slope under the platform. For this reason, and for others connected with the tidal currents, this point was selected for beginning the heavy wall, with a deep foundation, within about a foot of the harbor-line, along which line the bottom continues to slope downward, attaining a depth of 23 feet at low water in a further distance of about 400 feet.

This light wall was begun in March, 1874, the foundations having been partly prepared during the previous winter. It was completed in the autumn of the same year, except for a short distance where it connects with the heavy wall beyond, by a spur running out to the harbor line.

The settlement of this light wall is recorded in table A. Early after its completion, this wall was filled up to grade 13 with clay, and a large pile was left temporarily at a higher level near the beginning of the curve. Directly afterwards a forward movement of the wall was observed, about a foot in amount, and tapering out in about 200 feet of length each way. The pile of clay was soon removed by spreading on to adjacent spaces, and no further movement has been detected here since. The coping had been considerably disturbed by the hoisting of clay over it, and was reset in 1877, on a straight line, leaving the offset below the coping of slightly irregular width.

From the end of this light wall, for a distance of 803 feet along the coping, around the curve to the first dock, we have a heavy sea-wall, a section of which is shown on plate G. The face of this wall at the top is one and a half feet back from the harbor-line.<sup>1</sup> Its foundation is on the clay, 23 feet below low water. For

<sup>1</sup> When the work was laid out, it was intended to have the face at the top just one foot back of the harbor line; but the yielding nature of the material encountered under its base rendered it advisable to throw the centre of gravity further back, for the sake of greater stability, by making more batter in front.

12 feet in height it is built of broken quarry stones, dumped from vessels, and afterwards arranged with some compactness by divers with crowbars, in three layers of about four feet each. The base of this work is 45 feet thick, and its top is 18 feet thick, with slopes of one and a half base to one of height, and a depth of three feet along the edges, where large stones were used. The top layer was carefully levelled up with stone chips to receive the granite blocks; a straight edge some twenty feet long being used for this purpose by the divers, the ends of which rested on plank carefully spiked to temporary piles on each side at a level given by an assistant above. The dimension stone-work was therefore begun 11 feet below low water, with a thickness of 14 feet. It was composed of rectangular granite blocks, two feet thick, compactly laid by divers for five courses; the bottom course being all headers, and the successive courses above being alternately all stretchers and all headers, up to low water. Above this point the wall is laid in hydraulic cement, in courses of two feet each. The wall is five feet thick at the top, and batters nearly alike on its face and rear by offsets at each course. It is ballasted with gravel from the lower harbor up to within ten feet of the top, and for the rest of the height with oyster-shells. The pointing of this wall was originally of good American cement, applied under the contract; but it was found to have been considerably loosened by the frost during the two past winters between high and low water, and arrangements were therefore made to replace this pointing with Portland cement, where not perfectly sound. This was applied without sand, and promises to be more durable in this trying position.

The plan originally proposed for this wall is shown on plate E, except that no ballast was then provided either behind or under it. It was approved in 1868 by Major-Gen. J. G. Foster, Geo. R. Baldwin, James B. Francis, and T. Willis Pratt, four engineers of high standing. It was the plan contemplated in the contracts made at that time, which, however, were never approved by the Executive, and were therefore dropped.

Upon subsequently examining the character of the foundation on which this wall west of the dock was to rest, it was found that some parts of the clay bed were much softer than others, to such a degree that it was feared an unequal settlement would occur if this plan were to be carried out, so as perhaps to endanger its stability. Moreover, the slippery nature of the clay bottom might lead to its being pushed bodily forward when loaded by the filling behind it. It was found that a wall built on a foundation of broken

stone, as shown on plate G, would cost rather less than if built entirely of dimension-stone, while the inspection necessary to secure good work would also be less difficult. Moreover, though the weight of this broken stone would force the lower portions into the clay unequally, because of its unequal softness, thereby causing an unequal settlement when first applied, this unequal settlement would, it was thought, reach its limits before imposing the weight of the dimension-stone, so it could be levelled up after such settlement. After consultation with Mr. James B. Francis, C.E., this plan with the broken-stone base was therefore adopted for the portion of the wall under consideration. Work was begun by depositing the broken stone after dredging the trench, in April, 1874, and nearly the whole mass, or about 12,000 cubic yards, was deposited during that season, and partly levelled up after waiting for its settlement. Great pains were taken, and frequent inspection was made, as this work progressed, with the view to secure the greatest practicable degree of compactness in the material. Divers were employed by the State for this purpose, and what was much more efficient, the assistant engineer in charge, Mr. J. O. Osgood, made frequent inspections in diver's dress. The success of the structure is largely due to these precautions, without which such a foundation would be likely to give much trouble by subsequent unequal settling.

This wall as now built is certainly capable of resisting a much greater thrust without sliding forward on its bed than if the dimension-stone had been laid directly on the clay, for its base is composed of large, angular stones, embedded in the clay by the superincumbent load, while it covers by its base more than double the width of a wall built as at first proposed entirely of block-stone from the bottom. In constructing it, the broken stone, having been mostly deposited in 1874, were allowed to remain till the following year before proceeding with the dimension-stone above. In fact, only 1,200 cubic yards of the latter were laid prior to April, 1875. The unequal settlement of the broken stone actually taking place on the different qualities of material, really caused no practical inconvenience, for this work was levelled up after such unequal settlement had reached its apparent limits.

Early in 1875 this foundation was finally levelled up, and the granite blocks laid up upon it. Its completion occupied the whole of the years 1875 and 1876. It is now a year since it was loaded by the filling, and its stability has been quite satisfactory. The actual settlement of its lower course along its whole length and its progress in detail is given in the tables B and C together with



the present level of the top of coping above mean low water. The settling of the granite wall has taken place with such uniformity that scarce any cracks have been formed in the cemented joints of the coping. The largest crack had opened about one-fourth of an inch over a year ago at the top. It was repointed in 1876, and subsequently opened one-eighth of an inch. It has been again pointed in 1877, and now shows nearly one-sixteenth of an inch opening. The total motion is therefore less than half an inch, and appears to be decreasing. No forward or lateral movement has been detected in this wall, except the very slight one indicated by this crack. Not a stone has been broken by this movement.

In making contracts for the building of the heavy sea-wall east of the mouth of Fort Point Channel, provision had always been made for leaving openings for docks, which, it was supposed, could be constructed whenever the demand for their use might arise. As the filling of the neighboring flats progressed, it was found, early in 1875, that the material dredged from the harbor and lifted over the wall from which it was carried back by railways on trestles, and dumped from cars, had by such repeated handling been reduced from a stiff clay to a soft mortar, which spread out at a very flat slope, requiring from 15 to 20 feet horizontal for every foot of additional height. No temporary structure could be erected along the line of the dock to limit the spreading of this heavy material without a large expenditure, and it was therefore concluded to build the dock walls at once. The contract of June 30, 1875, provided for these walls, on a similar plan and at a similar cost with the light wall on Fort Point Channel already described, except that near their junction with the heavy wall where the sloping material in their front would be exposed more than elsewhere to the impact of harbor waves, provision was made to protect these slopes by a deposit of broken stone, at the rate of \$1.25 per ton. The size and shape of this dock is shown on plate F.

These dock walls were begun in 1875, and were nearly finished in 1876, the portions next the heavy walls being laid up in connection with the latter. After being ballasted, a considerable portion of the clay-filling was hoisted over the walls at different points, and allowed to spread back, taking a very flat slope; the remainder of the interior spaces being filled by dumping the material from cars on trestles. If the whole filling had been done from these trestles, without first loading the walls, — i.e., if the slope had been towards the walls instead of from them while being loaded, — they would doubtless have all been destroyed; for the material

took a slope of only three to five degrees above the horizontal, before losing its water. In table A will be found a record of the actual settlement of these walls, averaging about two inches up to this date; being chiefly due to the indentation of the bottom stone into the plank, and the springing of the plank to get a complete bearing on each pile-head.

Owing to the rapid filling of certain portions of the space during the last season, slight forward movements took place, as follows: At a point about 200 feet from the south-west corner of the dock, it moved forward six inches. At a point on the east side of the dock, about 25 feet from its junction with the heavy wall, it moved forward six inches. This motion did not appear to continue in any case beyond the period during which the semi-fluid clay was expelling the water with which it had been mixed by handling, and which floated out of it shortly after being dumped.

In providing for the strip of heavy wall along the harbor-line east of the dock on the flats belonging to the State, and between this and the dock on the flats of the Boston and Albany Railroad Company, the same reasons did not appear to exist for the base of broken stone twelve feet high which had existed on the portion described above, west of the dock. Between the two docks the foundation was quite uniform in texture, giving less reason than further west for unequal settlement, while the conditions of the back filling were such as to impose a lighter load per linear foot of the whole work; for this filling was only to extend against the central portion of its length, 156 feet only being filled out of a total length of about 180 feet, the dock walls being connected with it about 32 feet back from its ends. Still another reason appeared for adhering to the principal features of the original plan at this place; viz., the greater exposure here existing to the erosive effect of waves on the bottom, which might perhaps disturb a foundation of broken stones having a steep slope. It was therefore determined to adhere to a modification of the original plan for this part of the heavy wall which was built as indicated on plan E, the modification referred to being this: the foundation was dredged about four feet below the base of the wall, and the trench filled with small broken stones to diminish the risk of slipping. Previous, however, to advising this style of wall at this place, I had caused the bottom to be thoroughly tested as described in the report of Dec. 31, 1875, and published in the appendix of the Tenth Annual Report of your Board, to which report I would also make reference for a description of the methods adopted for testing the cement used in all the heavy walls above low water. Every barrel used has been thus

tested. The foundation for the 180 feet of heavy wall between the docks was prepared in the year 1876, as above described, by dredging three or four feet below its base, and levelling up with small broken stones from one to four inches diameter, carefully packed and levelled with a straight edge. During the year 1876, about seven courses of dimension-stone were laid upon this by divers, each course being alternately all headers and all stretchers up to low water. It has since been finished in cement masonry up to grade 16, the dock walls having been bonded into it as it was laid. The filling has but recently been applied; but, as the pressure of such filling against the wall is more severe immediately after its application than ever likely to be afterward, its present stability is an apparent guarantee for that of the future. A record of its settlement is appended in table D. The dimensions of the dock, with the shape and position of the walls, are shown on the accompanying diagram, marked plate F. The extra width of the proposed platforms along the dock walls, as we approach the harbor-line, is provided in order to allow of a flatter slope for the clay under these platforms at those points where most exposed to the erosion of harbor waves, and at the same time avoid the large extra cost of providing a deeper foundation of masonry for the wall, which would have been the only alternative; for the piles will not endure long unless covered with clay to protect them from worms. Near the outer end of the dock this slope will be essentially covered by the platform, which is to be there 40 feet wide; but along the inner portion of its length, this slope will extend out beyond the platform, though not to an extent which will be of inconvenience to vessels, which will have their keels in deep water.

In the following tabular statements (tables E, F, and G) will be found a record of the payments made under the contracts with Messrs. Clapp & Ballou, also a statement of the quantities of each kind of work done, with the nominal prices attached, by which partial payments have been made during the progress of the work, amounting, when finished, to the contract prices per lineal foot of wall, and square foot of filling.

TABLE A.

*Levels on the Fort Point Channel and Dock Walls.*  
(Referred to Mean Low Water.)

FORT POINT CHANNEL WALL. Distances from commencement of curve of 910 feet radius.	ELEVATION.		DOCK WALL. Lettered stations are about 50 feet apart.	ELEVATION.		DOCK WALL. Lettered stations are about 50 feet apart.	ELEVATION.	
	1874.	1877. December 8.		1876.	1877. December 8 and 10.		1876.	1877. December 10.
END OF WALL.			WEST SIDE.			EAST SIDE.		
314½ feet S. of P. C., .	16.00	15.62	Y, + 25,	16.00	15.89	S. E. corner, I — 7,	16.00	15.91
300 " "	16.00	15.79	X " "	16.00	15.86	I, + 25,	16.00	15.90
275 " "	16.00	15.73	X " "	16.00	15.84	J, + 25,	16.00	15.92
250 " "	16.00	15.65	W, + 25,	16.00	15.91	K, + 25,	16.00	15.87
225 " "	16.00	15.70	W, + 25,	16.00	15.87	L, + 25,	16.00	15.80
200 " "	16.00	15.56	V, + 25,	16.00	15.96	M, + 25,	16.00	15.86
175 " "	16.00	15.48	U, + 25,	16.00	15.94	N, + 25,	16.00	15.74
150 " "	16.00	15.48	T, + 25,	16.00	15.81	O, + 25,	16.00	15.92
125 " "	16.00	15.66	S, + 25,	16.00	15.69	P, + 25,	16.00	15.87
100 " "	16.00	15.66	R, + 25,	16.00	15.74	Q, + 25,	16.00	15.85
75 " "	16.00	15.73	Q, + 25,	16.00	15.77	R, + 25,	16.00	15.83
50 " "	16.00	15.78	P, + 25,	16.00	15.84	S, + 25,	16.00	15.88
25 " "	16.00	15.93	O, + 25,	16.00	15.83	T, + 25,	16.00	15.88
0 " "	16.00	16.06		16.00	15.83	U, + 25,	16.00	15.96
25 " "	16.00	15.94		16.00	15.83	V, + 25,	16.00	15.86
50 " "	16.00	15.66		16.00	15.93	W, + 25,	16.00	15.90
75 " "	16.00	15.82		16.00	15.77	X, + 25,	16.00	15.85
100 " "	16.00	15.86		16.00	15.83	Y, + 25,	16.00	15.92
125 " "	16.00	15.99		16.00	15.79	Z, + 25,	16.00	15.88
150 " "	16.00	15.98		16.00	15.76		16.00	16.00
175 " "	16.00	16.09		16.00	15.70		16.00	15.98
	16.00	16.02		16.00	15.74		16.00	15.94



200 feet N. of P. C.,	15.81	N + 25,	15.76	S, + 25,	16.00	15.92
225 "	15.94	N,	16.00		16.00	15.94
250 "	15.91	M + 25,	16.00	T, + 25,	16.00	15.91
275 "	15.90	M,	16.00	U, + 25,	16.00	15.82
300 "	15.71	L + 25,	16.00		16.00	15.69
325 "	15.71	L,	16.00	V, + 25,	16.00	15.86
350 "	15.80	K + 25,	16.00		16.00	15.89
375 "	15.80	K,	16.00	W, + 25,	16.00	15.94
Corner, Middle of Spur to Heavy Wall, . . . . .	15.88	J + 25,	16.00	X, + 25,	16.00	15.79
		I + 25,	16.00		16.00	15.95
		I,	16.00	Y, + 25,	16.00	15.84
		S. W. corner, I - 7,	16.00		16.00	16.00
	15.81		15.80	Corner, junction with heavy wall, . . . . .	16.00	15.79
						15.92
Average settlement, = . . . . .	0.19	Average settlement, = . . . . .	0.20		16.00	16.06
				Average settlement, = . . . . .	15.89	15.89
					0.11	
		END.		Mean of levels on the whole dock, . . . . .	. . . . .	15.84
		25 feet from S. W. corner, 50 "	16.00			
		75 "	16.00			
		100 "	16.00			
		125 "	16.00			
		150 "	16.00			
				Average settlement on whole dock, . . . . .	16.00	
					15.84	
					0.16	

TABLE B.

## Levels on Heavy Wall, West of Dock.

[Referred to Mean Low Water.]

	ELEVATION OF TOP OF BOTTOM COURSE.										Height of Wall above Bottom Course. (Bottom C = 2 feet.)	Elevation of Top of Wall (front line of caps) Dec. 8, 1877.
	Oct. 7, to Nov. 16, 1874.	Nov. 28, to Dec. 2, 1874.	April 1 and 2, 1875.	May 6, 1875.	May 21, 1875.	July 8 and 9, 1875.	Aug. 27, 1875.	Oct. 12, 1876.	Oct. 15, 1877.	Dec. 8, 1877.		
West end of wall A . . . . .	9.24	8.96	9.24	—	—	—	—	9.87	9.91	9.94	25.57	15.67
Dolphin No. 4, 29 } B . . . . .	8.98	8.96	8.90	—	—	9.18	—	9.76	9.80	9.81	25.41	15.60
feet from west } C . . . . .	9.03	9.02	9.06	—	—	9.18	—	9.87	9.92	9.96	25.53	15.57
end of caps } D . . . . .	9.11	9.12	9.11	—	—	9.20	—	9.89	9.93	9.96	25.47	15.51
E . . . . .	9.13	9.13	9.14	—	—	9.25	—	10.06	10.09	10.11	25.58	15.47
F . . . . .	9.11	9.12	9.11	—	—	9.27	—	10.10	10.15	10.18	25.58	15.40
G . . . . .	9.03	9.03	9.03	—	—	9.16	—	10.00	10.03	10.06	25.46	15.40
H . . . . .	8.97	8.97	8.99	—	—	9.08	—	9.88	9.90	9.93	25.40	15.47
I . . . . .	8.81	8.82	8.84	—	—	8.94	—	9.73	9.75	9.77	25.27	15.50
Dolphin No. 5 . . . . .	9.03	9.03	9.05	—	—	9.12	—	9.89	9.92	9.95	25.45	15.50
J . . . . .	8.95	8.94	8.95	—	—	9.06	—	9.82	9.85	9.89	25.35	15.46
K . . . . .	8.96	8.96	8.98	—	—	9.08	—	9.76	9.82	9.87	25.38	15.51
L . . . . .	8.92	8.92	8.92	—	—	9.10	—	9.73	9.78	9.85	25.31	15.46
M . . . . .	9.02	9.02	9.02	—	—	9.16	—	9.81	9.88	9.95	25.38	15.43
N . . . . .	9.03	9.05	9.03	—	—	9.12	—	9.81	9.84	9.90	25.36	15.46
O . . . . .	8.95	8.99	8.97	—	—	9.10	—	9.75	9.78	9.84	25.35	15.51
P . . . . .	8.96	8.99	8.97	—	—	9.10	—	9.70	9.73	9.77	25.29	15.52
Dolphin No. 6 . . . . .	9.03	9.04	9.05	—	—	9.11	—	9.74	9.76	9.80	25.33	15.53
Q . . . . .	8.97	8.98	9.00	—	—	9.09	—	9.73	9.75	9.77	25.36	15.59
R . . . . .	8.93	8.94	9.00	—	—	9.10	—	9.80	9.81	9.84	25.39	15.55
S . . . . .	8.90	8.91	8.94	8.94	—	9.08	—	9.76	9.78	9.80	25.38	15.58
T . . . . .	—	8.97	9.00	9.00	—	9.08	—	9.74	9.76	9.79	25.39	15.60
Dolphin No. 7 . . . . .	—	9.02	9.06	9.06	—	9.14	—	9.84	9.88	9.90	25.51	15.61
U . . . . .	—	—	—	—	—	—	9.17	—	—	—	—	—
V . . . . .	—	—	—	—	—	—	—	—	—	—	—	—
W . . . . .	—	—	—	—	—	—	—	—	—	—	—	—

Regular stations are 17.61 feet apart; Dolphins, 105.64 feet apart.

[illegible]





TABLE D.

LEVELS ON HEAVY WALL EAST OF DOCK. — (*Referred to Mean Low Water*).

Regular Stations are 20.42 feet apart.	Elevation of Bottom Course.		Height of Wall above Bottom Course (Bottom C. = 2 feet).	Elevation of Top of Wall (Front line of Caps), Dec. 20, 1877.
	Sept. 26, 1877.	Dec. 20, 1877.		
End of wall . . . . A,	—20.94	—20.94	37.01	16.07
B,	—21.04	—21.09	37.11	16.02
C,	—21.04	—21.07	37.12	16.05
D,	—21.00	—21.04	37.06	16.02
Dolphin No. 14, 73.6 ft. from W. } end of caps, . . . . E,	—20.96	—20.99	37.05	16.06
F,	—21.00	—21.03	37.11	16.08
G,	—21.00	—21.02	37.10	16.08
H,	—21.03	—21.06	37.17	16.11
I,	—20.95	—20.98	37.10	16.12
Dolphin No. 15, 105.1 ft. from } E. end of caps, . . . . J,	—20.94	—20.96	37.13	16.17
End of wall, . . . . K,	—20.93	—20.95	37.09	16.14
Mean of latest levels, . . . .	—	—21.01	37.09	16.08
Original elevation, top of bottom course, . . . .	—	—20.8		
Average settlement, . . . .	—	—0.21		
Greatest settlement, . . . .		—0.29		
Least settlement, . . . .	—	—0.14		

N. B. — The datum used for these levels is the same hitherto used in connection with the office of the Harbor Commissioners and Coast Survey. It varies slightly from the datum of the City Engineer's office. This datum can be found by the following bench-marks; viz., North-east corner of door-step of office of Boston Water Board's pipe-yard on Federal Street, opposite New York and New England Railroad station, is called 19.839; coping of Dry Dock in Navy Yard, 14.620.

TABLE E.

*Record of Payments made under the Contracts with Messrs. Clapp & Ballou.*

WORK DONE.	Lineal Feet.		Square feet of Filling.	Total value at the Contract prices.	Reserved under Contract.	Actually Paid.
	Light Wall.	Heavy Wall.				
Before Jan. 1, 1875,	641	255	190,016	\$160,139 00	\$16,013 88	\$144,125 12
“ Jan. 1, 1876,	1,138	743	349,216	357,682 26	35,768 20	321,914 06
“ Jan. 1, 1877,	2,415	879	561,692	525,228 21	52,522 82	472,705 39
“ Jan. 15, 1878,	2,635	944.849	884,010 <sup>6</sup> / <sub>10</sub>	676,313 68	67,631 33	608,682 35

These partial payments have been made according to the following list of nominal prices furnished by the contractor, amounting, when multiplied by the estimated quantities of each kind of work, to the contract price per lineal foot of walls; viz.:—

For wall along Fort Point Channel and around dock:

For piles and planking same, 2 piles per lineal foot, at \$5 each, \$10 00 per foot.

Digging out and applying ballast between piles, . . . 1 50 “

Masonry, 4 $\frac{3}{4}$  yards per foot, at \$3.32 + per yard, . . . 15 50 “

Ballasting back of wall, 7 $\frac{1}{2}$  yards per foot, at \$1.50, . . . 11 00 “

Guide piles, . . . . . 1 00 “

Total, . . . . . \$39 00 per foot.

TABLE F.

*The Quantities of Work actually done at the Various Points are about as follows, viz. :*

LOCALITY.	Length on Top.	Tons.	Cubic Yards.
Fort Point Channel wall, . . . . .	720 $\frac{49}{100}$	—	3,187 $\frac{951}{1000}$
Broken stone at north end, . . . . .	—	743	—
Heavy wall west of docks, . . . . .	802 $\frac{783}{1000}$	—	—
Heavy wall masonry laid by divers, . . . . .	—	—	3,794 $\frac{675}{1000}$
Heavy wall masonry in cement, . . . . .	—	—	3,639 $\frac{437}{1000}$
Heavy wall foundations of broken stone, . . . . .	—	20,500 or	12,904 $\frac{897}{1000}$
Heavy wall east of dock, . . . . .	132 $\frac{53}{100}$ *	—	—
Heavy wall masonry by divers, . . . . .	—	—	1,638 $\frac{871}{1000}$
Heavy wall masonry in cement, . . . . .	—	—	606 $\frac{157}{1000}$
Broken stone in foundation, . . . . .	—	923	—
Dock wall, . . . . .	1861.	—	—
Masonry . . . . .	—	—	8,241 $\frac{576}{1000}$
Broken stone at north-west corner, . . . . .	—	737	—
Broken stone at north-east corner, . . . . .	—	1,105	—
Broken stone under west wall, . . . . .	—	146	—

\* On State's lands.

TABLE G.

## NOMINAL PRICES USED FOR PARTIAL PAYMENTS.

For heavy sea-wall west of dock.

Broken stone in foundation, . . .	\$3.00 per yard.	
Levelling the same, . . . . .	.50 " "	
Guide piles for same, . . . . .	.05 " "	
15.5 cubic yards per foot length, . . .	\$3.55 " "	\$55.025 per foot.
Masonry below low water, 4,691 yards, @ \$18, . . .		84.438 " "
Masonry above low water, 4,531 yards, @ \$17.775, . . .		80.537 " "
Ballast behind wall, . . . . .		16.000 " "
Total, as per contract price, . . . . .		\$236.000 " "

For heavy wall between the docks.

Masonry laid by divers, 11.95 yards, @ \$15, . . .	\$179.25 per foot.
Masonry laid above water, 4,531 yards, @ \$10, . . .	45.75 " "
Levelling foundation, . . . . .	5.00 " "
Ballast behind wall, . . . . .	18.50 " "
Total, . . . . .	\$248.50 per foot.

*Dredging Done.*

While getting material for filling the area behind the above described walls, the following dredging has been done.

Fort Point Channel has been dredged on a slope as above described, reaching a depth of 23 feet at low water, at a point about midway the length of the heavy wall west of the dock. The portion of this channel opposite the light wall is 400 feet wide. Passing eastward, the width gradually contracts to about 200 feet before arriving at the first dock. Near the entrance to this dock, it is widened again to a width of 400 feet, with a depth of 23 feet at low water. This width allows vessels to turn in entering or leaving the dock. From this point, a channel is dredged about 200 feet wide and 23 feet deep at low water nearly due east to the main ship-channel. A considerable amount of material has also been taken from a shoal off the end of Long Wharf.

The dock on the Commonwealth's flats has a depth of 23 feet at low water through its whole length, up to within 50 feet of the walls on each side, which is as near the walls as it will be safe to dredge, before the platforms are built, owing to the difficulty in controlling the dredging machines with any exactness. This bank



of clay on each side will be a sufficient protection to the walls until the platforms are built, after which it may or may not be found necessary to dredge a small quantity along their front lines.

*Stability of the Heavy Wall between the Docks.*

Since this wall is constructed under somewhat novel conditions, it may be of interest to refer to the course of reasoning by which the forms adopted may be justified under the conditions actually existing. This wall is, except for a short distance at each end, to act as a retaining wall for the solid filling behind it, while the ebb and flow of the tides bring a mass of water in its front, varying some 12 feet in height, being from 22 to 34 feet in depth at spring tides. Since the lower 12 courses are laid without cement, the water passes freely through the wall, rising and falling with every tide among the material in its rear, as far as such material is not impervious to it. A porous ballast is placed immediately behind the wall; but beyond this, the material for 35 feet in height above its base is a slippery clay, reduced by handling to a semi-fluid condition when first deposited, and acquiring gradually a more solid character, by the expulsion of water from among its particles, through their greater specific gravity, which was about double that of sea-water. This is a slow process: the well-known characteristic of the material being a tendency to resist the percolation of water through its mass; so that many months elapse after its deposit, before it becomes as compact as when first found in the harbor. In this latter condition, we are obliged to use it as a foundation to build on. Before beginning the work, it had been found by actual experiment that this material would bear a load of some 5,000 pounds per square foot without flowing out perceptibly from under this load: also that an increase of load above this point, was soon accompanied by a tendency to flow, which was apparently continuous for a number of days when a load of 16,000 pounds per foot was applied. The quantity of clay to be moved by flow from under such a load would increase materially with the settlement of the load, for the first few inches of the displacement, by the accumulation of this displaced material, after which a channel might be established for its escape. A point of equilibrium seemed to be reached in our experiments, where a slight settlement taking place at first was checked by this increase of resistance, until, by successive applications of new loads, a load of about 16,000 pounds per foot was reached, when this settlement seemed to become continuous during the experiment. It was therefore considered desirable to limit the maximum load to 5,000 pounds

per foot if possible, although a heavier load might not produce much trouble within the limits of 7,000 or 8,000 pounds per square foot.

The amount and directions of the pressure exerted upon such a wall by the earth behind it, depend upon these two data: (A) The specific gravity of the material. (B) The natural slope of the material, when a bank of it is left to assume its own slope. This angle is the natural resultant of the friction of the particles as exerted to prevent sliding and the gravity of the mass. It is therefore sometimes called the angle of friction, and its tangent is the co-efficient of friction of the material.

Since the investigations of Prony, in the early part of this century, it has been accepted as proved, that the maximum pressure of earth in such cases is exerted, not by the whole prism lying between its natural slope and the back of the wall, for the tendency to slide in that prism is just balanced by friction, and it would not tend to move at all; but this maximum pressure is exerted by the prism contained between the back of the wall and a plane inclined upward from its base so as to bisect the angle between the vertical and the natural slope. The sliding of this prism downward would therefore throw the centre of pressure in the direction of this limiting plane on which the sliding takes place, i.e., parallel to it; and as the centre of gravity in such a prism, if homogeneous, would be at two-thirds the distance from the top of the wall to the centre of this sloping plane, the line of pressure would strike the back of the wall at a point one-third way up from the base. The value of the horizontal thrust on the wall at this point is expressed by the following formula: —

$$P = \frac{Wh^2}{2} \tan^2 \frac{1}{2} (90^\circ - \Phi)$$

Where  $P$  = horizontal pressure on wall for a unit of length.

$W$  = weight of a cubic unit of filling material.

$h$  = height of wall.

$\Phi$  = angle of repose of filling material, counting from the horizon.

In other words, this pressure for a unit of length of wall equals the product of the weight of the prism for a unit of length by the tangent of one-half the complement of the angle of repose: for the weight of such a prism is —

$$= \frac{W}{2}, h^2 \tan \frac{1}{2} (90^\circ - \Phi)$$

Of these elements the weight of the filling is easily obtained, and is found by experiment to be about 125 pounds per cubic foot.

The height of the wall is 39 feet. It only remains to find the angle of repose of the material. It is upon this point that all the uncertainty arises which enters into such calculations, and renders them often of little value. The natural slope of earth when not subject to the wash of water is generally taken at about  $33^{\circ} 18'$ . But the clay with which we have to deal possesses, when first deposited, almost the fluidity of mortar; and its natural slope is found to be as low as  $3^{\circ}$ , till time is given for it to expel the water with which it has been mixed. It follows, that a wall of enormous weight and breadth of base would be required to hold up such a filling for the period of its transition from a semi-fluid to a comparatively solid state; so that much economy would result by using plenty of time in so disposing this back filling as to increase the angle of repose as far as possible. The first step in this direction is to place in immediate contact with the rear of the wall a quantity of porous material, or ballast, which will not only drain the filling in the immediate neighborhood, but serve to increase the angle of the natural slope. Such material was provided for this purpose in the specifications; viz., porous gravel, stones, or oyster-shells. The gravel would have a natural slope of some  $33^{\circ} 18'$ , and the stones or shells, if used, a slope of  $40^{\circ}$ . But the prism of greatest pressure would not be composed entirely of such ballast. There would be a considerable amount of clay, and this would tend to make the whole mass slide at a flatter slope than the ballast alone would assume. The natural slope of the combination would be somewhere between that of the two substances considered separately. A large number of experiments made upon the friction of this clay led us to suppose that its angle of repose, when not mixed with water, was more dependent on its cohesion than friction; and a disposition to flow under extreme pressure was generally developed, even when at its hardest state. If we could rely upon the complete expulsion of the water from its mass before completing the loading of the wall, and if we chose to rely on cohesion, we might rely on a natural slope of some  $35^{\circ}$  perhaps for that of the ballast and clay together. But the difficulty of attaining this result, and the uncertain character of the element of cohesion, indicate that prudence would require the assumed angle to be less than that of common earth alone; say as small as two of base to one of height, or  $26^{\circ} 34'$  for the condition of things soon after loading the wall. In order to indicate the direction and value of the resultant pressure on this supposition, the annexed diagram is made (Plate H).

In this diagram the section of the wall is shown by the figure



ABD. The supposed natural slope of the material behind it, when partially consolidated, is shown by the line BF, with an angle of  $63^{\circ}26'$  from the vertical. The prism of maximum pressure would then be included between the lines BA and BE. It would tend to slide down the line BE, and, if composed of homogeneous materials, would give a line of pressure parallel to this side, and intersect the wall at one-third its height above its base. But we have here conditions somewhat different from these. The water passes freely through the wall and the ballast, so that the centre of gravity of the prism ABE would not be at the centre of gravity of this triangle. Extreme low water is evidently the time when the greatest earth pressure exists. But the material below the water at any time would not count at its full weight, but at a weight depending on its excess of specific gravity over that of sea-water. On computing the centre of gravity of the figure upon this basis we find it at the point C', and drawing thence the line C'H parallel with BE we find the line of pressure intersects the back of the wall at a point H, more than a foot above the lower third of the height of the wall. The weight of such a prism one foot long, allowing for the buoyancy of the water, is computed as 50.028 pounds, as indicated under the point C'. The horizontal pressure on the wall is then found by the formula above quoted.

$$P = w' \tan \frac{1}{2} (90 - \Phi)$$

$w'$  being the weight of the mass,  $A B E = 50.028$

$\Phi$  being  $26^{\circ} 34'$  and  $\frac{1}{2} (90 - \Phi)$  being  $31^{\circ} 43'$  from which we have

$$P = 30.920 \text{ lbs.}$$

We want now to combine this horizontal force with the weight of the wall. This is supposed to act from its centre of gravity, C, with a vertical force of 53.490 pounds; the portion below low water being diminished in weight by the buoyancy of the water, and the centre of gravity being higher than that of the figure. The resultant is found by computing the diagonal of the force parallelogram to be in a direction shown by the line IJK, making an angle of  $30^{\circ} 02'$  with the vertical, and having a value of 61.790 pounds. This would intersect the base at K, distant 3.85 feet from the outer corner of the wall, and would indicate a degree of instability from the following reasons. The angle  $30^{\circ} 02'$  is somewhat greater than the angle of friction between stone and stone, as generally accepted, and decidedly greater than that between stone and clay. This might lead to the sliding forward of the wall. Moreover, the pressure on the base is not uniform, but has a maximum at the point D of some 8.500 pounds per square foot, even suppos-



ing the horizontal component of this resultant to be cancelled by friction. It had been found by our experiments above referred to, that a pressure of this amount on the clay-bed under the wall began to produce symptoms of flow from under the load, hardly consistent with stability.

But we have thus far neglected the items of water pressure and friction between the filling and the back of the wall. Since a very slight rolling motion in the wall might take place about the point B, without producing friction on the line BA, it was not thought prudent to rely on this; although Mosely and some other writers suggest such a reliance. But the water-pressure certainly does act to some purpose in assisting stability. For although it flows freely through the wall and the ballast, it meets, sooner or later, an impervious material, against which it stops and exerts the known pressure, and a part of this may doubtless be reckoned upon to hold back and cancel, *pro tanto*, the earth pressure. A line is drawn on the diagram showing the water-pressure at extreme low water intersecting the front of the wall and normal to it, at a point one-third the height from the bottom to top of the water, having a value of 14.112 pounds. If the wall were a tight diaphragm, this would produce the resultant JL, when combined with the above described forces. In reality this resultant may be considered to lie between the lines JK and JL. The latter has an angle of  $73^{\circ} 10'$  with the horizontal, or  $16^{\circ} 50'$  with the vertical, which is evidently within the limits of stability.

The result of the above investigation indicates that it is desirable to keep the material behind the wall in such a condition that the angle of repose would always be slightly greater than here shown, which is a condition verging on the extreme limits of stability. This end can generally be attained by giving attention to the manner in which the filling is deposited; viz., to insure its being deposited in successive layers, giving time for the consolidation of each layer by the expulsion of water from among its particles before applying the next one, and giving each successive layer a slope *from* the wall, by keeping the material highest next the wall. These well-known rules in the application of filling behind a retaining wall are particularly important when using a material like this clay, which acts more like a fluid than a granular substance, and is always inclined to flow under pressure, even when consolidated as far as possible, the only condition being that the pressure shall overcome its cohesion, a power of resistance difficult to determine, and which all prudent engineers hesitate to rely upon.

The above investigation also indicates the apparent lack of sta-

bility in case the wall were to be founded directly upon the clay, as at first proposed in 1869 ; for the friction of granite blocks upon clay is far inferior to that of the same blocks upon the broken stone, while the latter, being embedded or indented into the clay at the bottom of the trench, get a far better hold than flat stones would do, resting on a flat clay bottom.

Before closing this report, the writer wishes to express his obligations to Mr. Joseph O. Osgood, your inspector, to whose faithful attendance, good judgment, and conscientious thoroughness in the discharge of his difficult duties, the success of these walls is largely due.

Respectfully submitted by

EDW'D S. PHILBRICK,  
*Engineer in Charge.*

BOSTON, Jan. 14, 1878.

[B.]

REPORT OF OPERATIONS ON THE IMPROVEMENTS  
OF THE RIVERS AND HARBORS, IN THE  
STATE OF MASSACHUSETTS,

UNDER CHARGE OF

*Bvt. Brig.-Gen. George Thom, Lieut.-Col. of Engineers, U. S. Army,*

FOR THE YEAR ENDING Dec. 31, 1877.

## I. IMPROVEMENT OF BOSTON HARBOR, MASSACHUSETTS.

The additional work projected for the improvement of this harbor, during the season of 1877, under the appropriation made therefor by Congress, in the River and Harbor Act of Aug. 14, 1876, was as follows, viz. :—

1. Widening, straightening, and deepening the Main Ship Channel at and near the south-west point of Lovell's Island, so as to have a depth of 23 feet at mean low water (or about  $32\frac{1}{2}$  feet at ordinary high water), for a width of not less than 600 feet, requiring about 30,000 cubic yards of dredging.

2. Breaking up and removing about 290 cubic yards of sunken ledge lying in the Main Ship Channel at the Upper Middle Bar, and near Kelly's Rock ; and,

3. The removal of numerous sunken rocks (bowlders and ledge) scattered over Nash's Rock Shoal, situated in the entrance of Boston Harbor, so as to have a depth of not less than 21 feet throughout at mean low water, giving an increase of about 6 feet over its shoalest parts.

On the 2d of June last a contract was made with the New England Dredging Company, of Boston, Mass. (the lowest of eight bidders), for the dredging required at and near the south-west point of Lovell's Island at 24 cents per cubic yard, as measured in the scows. This work was commenced on the 19th of June, and was satisfactorily completed on the 27th of September, 1877.

This improvement, together with the dredging completed in 1875 at the south-east point of Lovell's Island, and that in 1876 at the west end of Great Brewster Spit and at the Upper Middle Bar, finishes all the *dredging* hitherto projected for the improvement of this harbor, from its entrance up to Anchorage Shoal, giving a channel not less than 600 feet in width, and 23 feet in depth at mean low water (or about  $32\frac{1}{2}$  feet at ordinary high water), except where obstructed by the sunken ledges recently discovered near Kelly's Rock, and in the Upper Middle Channel, yet to be removed.

The sunken ledge in the Upper Middle Channel (which was laid bare last season by dredging) contains  $81\frac{1}{2}$  cubic yards of rock to be broken up and removed, in order to obtain the projected depth of 23 feet at mean low water: for the accomplishment of which a contract was made, June 4, 1877, with Mr. George W. Townsend, of Boston Mass. (the lowest of two bidders), at \$65 per cubic yard as measured in its bed, the work to be completed next season. This same contract also provides for the breaking up and removal of about 200 cubic yards of the sunken ledge near Kelly's Rock, at \$50 per cubic yard as measured in its bed, also to be completed next season. The contractor commenced operations on the 15th of June last, upon the ledges above (to the westward of) Kelly's Rock, requiring the removal of  $26\frac{4}{10}\frac{2}{10}$  cubic yards, for obtaining the projected depth of 23 feet at mean low water, and completed the same on the 18th of August last; since which time he has been at work on one of the ledge-spurs below Kelly's Rock, containing about 180 cubic yards to be removed for obtaining the required depth. Owing to the very unfavorable weather for these operations, in such an exposed position, the progress made has been much less than would have been expected from the experience of previous years; 50 cubic yards, only, of that ledge-spur having been broken up, and removed down to grade, at this date. This work has been suspended till next season, when better progress may be hoped for.

The work for the improvement of Nash's Rock Shoal was commenced on the 4th of September last, and continued until the 8th of November, when, owing to the very windy weather and strong currents in that exposed position, it was suspended till next season. This work was done by a submarine party, with a vessel and crew hired by the day, by which about 320 tons of large bowlders have been removed during the season, leaving about 40 tons only to be removed for the completion of the work, next season. By the operations of the past season, this shoal has been



so far improved, that on its shoalest parts there is now a depth of  $18\frac{1}{2}$  feet at mean low water, being an increase of over 3 feet.

*Sea-Walls.* — In addition to the several works above referred to, sea-walls have been built for the protection and preservation of the headlands in this harbor, at Point Allerton, Great Brewster Island, Lovell's Island, (north head and south-east bluff), Gallop's Island, Long Island (north head), and Deer Island (north, middle and south heads). All these sea-walls, with the exception of that on the south-east bluff of Lovell's Island, and those on Deer Island, are in good condition; all the most necessary repairs having been made on them, excepting on the one at the south-east bluff of Lovell's Island. For raising and repairing this wall, as now contemplated, an appropriation was asked for in my last annual report.

*Sunken Rocks.* — The removal of Kelly's Rock, Tower Rock, Corwin Rock, the rocks recently discovered at the west end of Great Brewster Spit, and between there and George's Island, — all situated in the Main Ship Channel at "the Narrows," — have been removed to a depth of 23 feet at mean low water, as stated in my last annual report. Barrel Rock in Broad Sound, State and Palmyra rocks, about one-half a mile east of Castle Island, have also been removed. So that the only work that now remains to be done for completing all the work hitherto projected for the improvement of this harbor consists of the following, to wit: —

1. Removal of $81\frac{1}{2}$ cubic yards of sunken ledge in the Upper Middle Channel, now contracted for, at \$65 per cubic yard	\$5,297 50
2. Completing the removal of $181\frac{1}{2}$ cubic yards of sunken ledge <i>below</i> Kelly's Rock now contracted for, at \$50 per cubic yard	9,075 00
3. Breaking and removing 150 cubic yards of sunken ledge, additional, <i>below</i> Kelly's Rock (recently discovered), at say \$50 per cubic yard	7,500 00
4. Completing the improvement of Nash's Rock Shoal, say	1,000 00
5. Raising and repairing the sea-wall on the south-east bluff of Lovell's Island, estimated at	15,000 00
6. Deepening Man-of-War Shoal by dredging, at an estimated cost (for 65,000 cubic yards of dredging), say	39,000 00
7. Engineering expenses and other contingencies, say	8,904 22
Total	\$85,776 72
Balance of appropriation available for above works, Dec. 31, 1877	25,776 72

Additional amount required for completing all the works hitherto projected for the improvement of this harbor . \$60,000 00

The above estimates do not include the improvement of Anchorage Shoal (next above the Upper Middle), now the only remaining obstacle to the free passage of ocean steamers and other deep-draught vessels from the ocean up to the inner harbor of Boston, in all stages of the tide.

A recent survey of this shoal shows that it has a very irregular shape, and extends into the Main Channel chiefly from the East Boston and Bird Island flats, having on its shoalest part but  $15\frac{1}{2}$  feet of water at mean low water (or about 25 feet at ordinary high water) ; that the greatest depth that can be carried over its southern part is 22 feet at mean low water for a width of about 350 feet, or 21 feet for a width of about 500 feet. To open the channel to a depth of 23 feet at mean low water, for a width of 900 feet (the least width that is adequate for this part of the channel) would require about 85,000 cubic yards of dredging over an area of about 80,000 square yards of the shoal, the estimated cost of which, at 62 cents per cubic yard, is (including contingencies), say \$60,000 ; or, for a width of 1,100 feet, over an area of about 130,000 square yards, about 130,000 cubic yards of dredging, the estimated cost of which is (including contingencies) say \$90,000.

The improvement of the channel at this shoal has hitherto been included in the project of the Board of Harbor Commissioners of the State of Massachusetts, for the reclamation of South Boston flats (now in part approaching completion), as shown in their report and accompanying drawings for January, 1868, — it having been supposed that the material to be excavated would be wanted for filling those flats, back of the projected sea-walls. Some portion of the area between Anchorage Shoal and the sea-wall has already been excavated in accordance with the original project ; but there is now no prospect, I learn, that the material forming Anchorage Shoal will be required for back filling for many years to come, if at all. Under these circumstances, and owing to the importance of having this improvement completed at as early a day as practicable, there appears to be no reason why it should not properly and consistently be done by the United States Government, in furtherance and completion of the work now so nearly accomplished for the permanent improvement of this important harbor.

## II. IMPROVEMENT OF MERRIMAC RIVER, MASSACHUSETTS.

The project adopted for the improvement of this river consists in deepening it by dredging, and the removal of sunken rocks, so that it shall have a channel 12 feet in depth at ordinary high-

water from its mouth at Newburyport, Mass., up to Haverhill, Mass., — a distance of fifteen miles ; and thence for a distance of about four miles up through “ the falls,” — a depth of four feet in the ordinary stages of the river.

During the past season, with the small available balance on hand, the channel of this river has been very much improved near Silby’s Island, about one mile below Haverhill, by the removal of a large number of sunken bowlders, which had hitherto been dangerous and serious obstructions to navigation. This completes all work now projected for the improvement of this river above Newburyport. For completing the contemplated improvement of the harbor of Newburyport, an additional appropriation of \$25,000 was again asked for in my last annual report, no appropriation having been made therefor by Congress in its last River and Harbor Act of Aug. 14, 1876.

### III. IMPROVEMENT OF PLYMOUTH HARBOR, MASSACHUSETTS.

The work projected for the further improvement of this harbor has been suspended since July, 1876, no appropriation having been made therefor by Congress since then.

### IV. IMPROVEMENT OF PROVINCETOWN HARBOR, MASSACHUSETTS.

The work projected for the preservation and further improvement of this harbor, under the appropriation of \$4,000 made by Congress in the River and Harbor Act of Aug. 14, 1876, consisted of —

1. Raising and extending the stone bulkhead on the extremity of Long Point, the stone therefor to be furnished by contract ; and

2. Repairs of the bulkheads and jetties at Beach Point and Cove Section, and of the dikes at High Head and Abel Hill where necessary, and planting beach-grass on the outer beach, this work to be done by men hired by the day.

The two contracts for furnishing all the large and small stone required for raising and extending the stone bulkhead on the eastern extremity of Long Point were completed in September last, under which 1,860 gross tons of stone were delivered and placed upon the work, in completion of the same to the extent now contemplated.

During the past month (December), all the repairs have been completed, where necessary, upon the works at Cove Section, High Head, and elsewhere.

All the works, therefore, that have been projected for the preservation and improvement of this harbor are now completed, and are as follows : —



1. Bulkheads and jetties of various descriptions have been built from time to time along Beach Point, for its preservation and protection, both by the United States Government and by the local authorities.

2. A dike was built in 1868 and 1869 by the State of Massachusetts across the outlet of East Harbor Creek.

3. A dike was built in 1868 and 1869 by the United States Government across East Harbor Creek, at the Wading Place, near High Head, about two miles above the outlet of the creek.

4. Wooden bulkheads and jetties have been built at different times for the protection and preservation of the beach on Long Point.

5. A stone bulkhead has been completed for the protection and preservation of the outer end of Long Point, the light-house, and three-gun battery.

6. A dike (272 feet in length) was built in 1871-2 across the head of Lancey's Harbor, near Abel Hill.

7. Beach-grass planted on Beach Point, Long Point, Abel Hill, Cove Section, and Oblique Section; and at the last two places brush has also been laid for their further protection.

8. The projected extensions of the several jetties on Beach Point and State Dike have been completed.

8. A bulkhead and six jetties, built in 1874 for the preservation and protection of the beach at Cove Section, near High Head, where encroached upon by the extraordinary gales of November, 1873, and January, 1874. This bulkhead is 607 feet in length, and the jetties have an aggregate length of 126 feet. They consist of a framework filled with brush and ballasted with stone.

All the above-described works are now in excellent condition, and have fully answered the purpose for which they were designed. They will, however, require continual watching and occasional repairs, exposed as they are to injury from the violent storms which at times occur in that locality. For this purpose an additional appropriation of \$1,000 has been asked.



[C.]

## ABSTRACT OF REPORT OF GEN. G. K. WARREN

TO

*Chief of U. S. Engineers, for 1877.*

## B 1.

## HYANNIS HARBOR, MASSACHUSETTS.

The history of the improvement in this harbor, the condition of the breakwater, and the necessity for further appropriation to complete the repairs, are given in my report for 1875. (See report of the Chief of the Engineers for 1875, Part II., pp. 266-268.)

Nothing has been done during the fiscal year because of the small amount of money available. The work does not appear to have sustained any notable injury during the year, but it needs strengthening at the base; and it is for this purpose that a further appropriation is required. The estimate for repairs made by me in 1874 was \$25,000: of this, but \$15,000 have been appropriated.

The light-house should be rebuilt, and placed on the east end of the breakwater, as has been suggested in previous reports.

Hyannis is in the Barnstable collection-district. Barnstable is the nearest port of entry. The amount of revenue collected there in the year ending June 30, 1877, is not known to this office.

*Money Statement.*

July 1, 1876, amount available, . . . . .	\$42 94
July 1, 1877, amount available, . . . . .	42 94
Amount (estimated) required for completion of existing project, . . . . .	10,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879, . . . . .	10,000 00

## B 2.

## WAREHAM HARBOR, MASSACHUSETTS.

A survey of this harbor was made in 1871, and a plan of improvement, including the removal of a ledge and bowlders at the

mouth of the Weweantic River, with estimate of cost, was submitted in December of that year by Gen. George Thom, lieutenant-colonel of engineers.

This plan of improvement was for a channel 250 feet in width through Quahaug Bar, and 9 feet deep at mean low water, requiring the removal of 41,260 cubic yards; and also the widening and straightening of the channel below the Franconia Iron Works, requiring the removal of 45,300 cubic yards. The total of 86,560 yards was estimated to cost at the rate of 45 cents per cubic yard:—

86,560 cubic yards, at 45 cents,	. . . . .	\$38,952
Contingencies,	. . . . .	3,048
Removing ledge and bowlders at Weweantic,	. . . . .	3,000
Total,	. . . . .	<u>\$45,000</u>

By Act of Congress approved June 10, 1872, \$10,000 was appropriated for this work. The work came under my charge June 30, 1872.

A contract for dredging at  $34\frac{1}{2}$  cents per cubic yard was made after duly advertising for proposals. Congress, by Act approved March 3, 1873, appropriated \$10,000 for continuing the improvement. A contract for continuing the work was made under this appropriation at  $36\frac{3}{4}$  cents per cubic yard. Under these contracts there was removed:—

	Cubic Yards.
At Quahaug Bar,	. . . . . 21,862
At Upper Harbor and up to the wharves,	. . . . . 24,901
Total,	. . . . . <u>46,763</u>

Also one bowlder weighing about 28 tons.

During the progress of this improvement another survey was made of the harbor, from which a revised estimate was submitted. The report upon this survey is printed in the report of the Chief of Engineers for 1874, pp. 216-220.

The amount of this revised estimate was \$20,000 in addition to what had already been expended; it called for the removal of 41,186 cubic yards from different parts of the channel, and for the removal of rocks to the amount of \$3,000 at "Four Buoys," near the entrance to the harbor, although this place had not been included in our surveys.

By Act of Congress approved June 23, 1874, \$10,000 was appropriated. A contract was made for continuing the improvement at 20 cents per cubic yard, under which 43,514 cubic yards were removed. By Act of Congress approved March 3, 1875, \$10,000

were appropriated for this work. A contract was made at the rate of 20 cents per cubic yard. Under this contract, 33,397 cubic yards were removed.

The whole quantity dredged in this harbor has been :—

	Cubic Yards.
Up to 1874, . . . . .	46,763
In 1875, . . . . .	43,514
In 1876, . . . . .	33,397
Total, . . . . .	<hr/> 123,674

This quantity is nearly 50 per cent more than was estimated for, which we were enabled to do on account of the price per yard being less than estimated. The channel made is from 250 to 300 feet wide, and 10 feet deep at mean low water from Long Beach, at the entrance of the harbor, up to the upper bar; thence to the bridge at the upper end of the harbor it is from 100 to 300 feet in width, and 9 feet deep at mean low water.

During the past fiscal year a survey was made at the "Four Buoys," where the channel into the harbor passes near a rocky point, which lies about 4,000 feet outside of Long Beach. The channel here, for a distance of about 600 feet, is about 200 feet in width, with a depth of from 13 to 16 feet at mean low water. On either side of this channel are numerous bowlders of varying sizes, lying on the bottom, the removal of which would be attended with an expense far in excess of the benefit to be derived.

We could not learn that any vessel had ever struck them to cause any great damage to themselves. The channel through this reef is marked by four buoys, two at each end. A straight line drawn between the two buoys on the left side of the channel would leave some bowlders on the channel side; but, as neither the flood nor the ebb tide sets on this point, it is not regarded as an important matter. The pilots say, "We always give the black buoys a good berth coming in," and therefore they have not struck the rocks outside of the line. Above and below the "Four Buoys" there is a good "beating" channel. A map accompanies this report, showing the improvement, and the channel at "Four Buoys."

The formation of Quahaug Bar, just inside of Long Beach, is by some people attributed to the sand carried over the beach in storms from the shoal outside. While this may not be the sole cause of the bar, there is a large amount of sand deposited there from this source. To prevent this, it is proposed to use the available funds in building a brush fence along the beach, weighting it with stone found above low-water outside of the beach. This fence is

designed to raise the beach above high-water, and by arresting this sand to hold it there permanently.

This improvement will then be completed ; and no further appropriation is needed, unless a greater capacity of harbor shall be required than when the plan was adopted.

Wareham is a port of delivery. It is in the New Bedford collection-district, and New Bedford is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1876, was \$9,710.04.

*Money Statement.*

July 1, 1876, amount available, . . . . .	\$7,024 78
July 1, 1877, amount expended during fiscal year, . . . . .	4,967 04
	<hr/>
July 1, 1877, amount available, . . . . .	\$2,057 74

B 3.

NEW BEDFORD HARBOR, MASSACHUSETTS.

The survey upon which the plan and estimate for the improvements were based was made in the summer of 1874, and the report submitted Nov. 30, 1874. This was printed as part of H. Ex. Doc. 75, Part III., Forty-third Congress, second session ; and in the Annual Report of the Chief of Engineers for 1875, Part II., pp. 283-285.

With the appropriation of \$10,000 made by Act of Congress approved March 3, 1875, a channel 105 feet wide and 15 feet deep at mean low water was made from the deep water near Fairhaven wharves to the deep water at the New Bedford wharves. The line of the new channel was slightly changed from the first design to get better ranges.

The appropriation of \$10,000 made by Act of Congress approved Aug. 14, 1876, was not made available until April 30, 1877. Advertisement inviting proposals was made May 8, 1877 ; and on the 8th of June the following were received : —



*Abstract of Proposals received at the Engineer Office, United States Army, Newport, Rhode Island, June 8, 1877, at 10, A.M., for Dredging in New Bedford Harbor, Massachusetts.*

Number.	Name and address of bidder.	Price per cubic yard.	Commence.	Complete.	\$9,000 will pay for cubic yards.
		<i>Cents.</i>			
1	W. H. Molthrop, New London, Conn.,	10½	"Soon as required,"	November 30, .	87,805
2	H. N. & A. J. Beardsley, Bridgeport, Conn.,	11½	August 1, . . .	December 1, .	78,260
3	T. C. Jeffers, Albany, N.Y.,	13	June 20, . . .	November 30, .	69,231
4	Morris F. Brainard, Albany, N.Y.,	13½	July 1, . . .	November 30, .	64,864
5	Providence Dredging Company, Providence, R.I.,	15	June 20, . . .	November 30, .	60,000
6	John H. Fenner, Albany, N.Y.,	17	June 20, . . .	November 30, .	52,941
7	Morris & Cummings Dredging Co., New York City, . . .	20	- -	November 30, .	45,000
8	William Flannery, New York City, . . . . .	23	June 20, . . .	November 30, .	39,130

The contract was awarded to William H. Molthrop, of New London, Conn.

In my last annual report on this work I recommended an additional appropriation of \$4,000, to complete the improvement in accordance with the original plan and estimate. The low price at which the work has been contracted for this year will, it is thought, enable us to complete the improvement with the present appropriation.

New Bedford is in the New Bedford collection-district, and is a port of entry. The amount of revenue collected there in the fiscal year ending June 30, 1876, was \$9,710.04.

#### *Money Statement.*

July 1, 1876, amount available, . . . . .	\$73 87
Amount appropriated by Act approved August 14, 1876, . . .	10,000 00
	<hr/>
	\$10,073 87
July 1, 1877, amount expended during fiscal year, . . . .	419 27
	<hr/>
July 1, 1877, amount available, . . . . .	\$9,654 60

#### B 4.

#### TAUNTON RIVER, MASSACHUSETTS.

The only work done on this improvement since the end of the last fiscal year has been the removal of 93.18 cubic yards of rock from Peter's Point and the "Nook."

To make the channel so as to allow vessels of 9 feet draught to reach Taunton at high water without difficulty will require the dredging of a sand-bar above Berkley Bridge, and the removal of isolated boulders between the "Needles" and Wickamont. The least width in the cuts is 60 feet.

Sixty thousand dollars have been appropriated and spent for this river. The \$5,000 now asked for is an increase above my former estimate for accomplishing the object intended, owing to the discovery of more obstructions.

A history of this improvement may be found in Annual Report of Chief of Engineers for 1876, Part I., pp. 205, 206, and in Annual Report for 1875, Part II., p. 285.

Taunton is in the Fall River collection-district, and that place is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1876, was \$6,372.35. The business done in Taunton River is large.

#### *Money Statement.*

July 1, 1876, amount available . . . . .	\$1,205 90
July 1, 1877, amount expended during fiscal year . . . . .	1,104 97
	<hr/>
July 1, 1877, amount available . . . . .	\$100 93
	<hr/>
Amount (estimated) required for completion of existing project	5,000 00
Amount that can be profitably expended in fiscal year ending	
June 30, 1879 . . . . .	5,000 00

#### B 5.

##### FALL RIVER HARBOR, MASSACHUSETTS.

At the beginning of the fiscal year the amount available for this work was \$597.55. By Act of Congress approved August 14, 1876, \$10,000 was appropriated for it. This appropriation was not made available until April 30, 1877.

Advertisements inviting proposals were issued May 8, and on June 8 the following were received:—

*Abstract of Proposals received at the Engineer Office, United States Army, Newport, Rhode Island, June 8, 1877, at 10, A.M., for Dredging in Fall River Harbor, Massachusetts.*

Number.	Name and address of bidder.	Price per cubic yard dredging.	Price per cubic yard rock.	Average on basis 2 per cent rock.	Commence.	Complete.	\$9,000 will pay for cubic yards.
1	J. H. Fenner, Albany, N. Y.,	\$0 55	\$8 40	.707	June 20, .	Nov. 30,	12,729+
2	William Flannery, New York City,	73	8 50	.8854	June 20, .	Nov. 30,	10,167
3	William H. Malthrop, New London, Conn.,	93	93	.93	{ Soon as required. }	Nov. 30,	9,677
4	Morris & Cumings Dredging Co., New York City,*	98	98	.98	June 20, .	Nov. 30,	9,183½
5	Morris F. Brainard, Albany, N. Y.,	75	13 00	.9950	July 1, .	Nov. 30,	9,046
6	T. C. Jeffers, Albany, N. Y.,	1 50	7 00	1.61	June 20, .	Nov. 30,	5,590

\* Provided bowlers do not exceed 2 per cent.

A contract has been made with the lowest bidder, John H. Fenner, of Albany, N. Y.

In the plan submitted for the improvement of this harbor, in report dated Dec. 31, 1873 (see Annual Report of the Chief of Engineers for 1874, pp. 284–286, Part II.), the estimated cost was \$45,000, and \$30,000 has been appropriated.

The prices at which the work has been done have been so much less than estimated, that the funds now available will complete the improvement as designed, should the bowlders not be more numerous than they have been in the part of the channel already deepened. The improvement designed was to make a channel to and along the wharves 12 feet deep at mean low water, the mean tide being 4 feet. This channel is to be about 100 feet wide in the middle, widening to 300 feet at each end. Before it was begun the depth varied from 5 to 12 feet.

Fall River is in Fall River collection-district, and is a port of entry.

The amount of revenue collected there during the fiscal year ending June 30, 1876, was \$6,372.25.

*Money Statement.*

July 1, 1876, amount available,	\$597 55
Amount appropriated by Act approved Aug. 14, 1876,	10,000 00
	<hr/>
	\$10 597 55
July 1, 1877, amount expended during fiscal year,	341 08
	<hr/>
July 1, 1877, amount available	\$10,256 47





ANNUAL REPORT

OF THE

BOARD OF HARBOR COMMISSIONERS

FOR

THE YEAR 1878.

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BOSTON :

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117 FRANKLIN STREET.  
1878.



# Commonwealth of Massachusetts.

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## HARBOR COMMISSIONERS' REPORT.

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*To the Honorable the Senate and the House of Representatives of the Commonwealth of Massachusetts.*

THE Board of Harbor Commissioners, in accordance with the provisions of law, respectfully submit their Annual Report for the year 1878.

### SOUTH BOSTON FLATS.

The substantial completion of work under the Clapp and Ballou contracts was announced in the last Annual Report. The possession of the filled territory has been transferred to the Land Commissioners, together with all personal property of the Commonwealth used in connection with the work of reclamation. A tabular statement of the precise location of points, which was not completed at the time of the last report, with plan illustrating the same, will be found in the Appendix.

The contractors' claims for extras, damages, &c., which were under examination at the time of the last report, seemed to the Commissioners entirely untenable as to the principal items, and they were unable to adjust the same with the contractors; but all items which seemed to them to have any equitable foundation, amounting to \$4,548.81, were allowed and paid. A petition was then presented by the contractors to the Governor and Council, who were the arbiters provided by the contract, submitting a claim for the items disallowed by

the Commissioners, amounting to \$201,709.41. While this petition was pending, and before hearing upon its merits, a board of arbitrators was created by chap. 281 of the Acts of 1878, and authority given to the Harbor Commissioners to join the contractors in a submission of the claims in question to the board thus established. It was supposed, at the time of the passage of the Act, that the hearing before the arbitrators would proceed at once in the month of June. Mr. Philbrick the engineer, and Mr. Osgood the inspector, who had been retained in service during the investigation of the claim by the board, were continued till the 1st of July, in expectation of an early assignment of the hearing. Difficulties arising out of proceedings in bankruptcy against the contractors continued to prevent the execution of the submission; and the board did not feel justified in continuing the employment of Messrs. Philbrick and Osgood, in view of the entire uncertainty when the submission could proceed. The proceedings in bankruptcy were dismissed on the 20th of September; and the board were immediately afterward informed by the counsel for the contractors of the removal of all obstacles to the submission, and of their readiness to proceed. The illness and death of Judge Thomas, the counsel for the board, occasioned some further delay in perfecting the formal submission; but, on the 16th of October, the submission agreement, in the form as it had been approved by Judge Thomas, was executed. Other counsel approved by the Governor and Council, were employed; and the arbitrators assigned the 16th of January, 1879, for the commencement of the hearing. Immediately after this assignment, the board communicated with Mr. Osgood, then in the employ of the Atchinson, Topeka, and Santa Fé Railroad Company, and were surprised to learn that it would not be practicable to secure his presence East before spring, by reason of the pressure of his employment at the West. Mr. Osgood's intimate knowledge of all the details of the work out of which the claims in question arise renders his presence at the hearing of great importance; and, if it were to proceed to a conclusion in his absence, the Commonwealth's interests would be at great disadvantage. It may be necessary for this reason to extend the time within which the arbitrators' award must be returned to the court under the provisions of the Act before cited.



The failure of the Boston and Albany Railroad Company to complete the filling of the 50 acres purchased of the State by them, and to construct the sea wall in front of the same, hinders the progress of the harbor improvement contemplated by the entire reclamation; but the Commonwealth having completed the 25-acre parcel, it is hoped that steps will be taken by the company to proceed to the completion of the wall and the dredging required of them, without further delay.

#### DREDGING IN BOSTON UPPER HARBOR.

The dredging in progress upon the shoal ground off East Boston frontage, at the time of the last Annual Report under contract with W. S. Fretch & Co., has been completed. Dredging has been continued upon the same shoal within the year, which has further extended the area of 23 feet depth, at mean low tide, one hundred and fifty-five thousand five hundred and seventy (155,570) square feet. The contract for this dredging was made with Charles Woolley & Co., on the 26th day of June; and the work was completed, and tested by soundings made by the engineer of the board, on the 13th day of December. The contract price was \$9,909, the contractor taking all risk of quantities and character of the material. The amount of earth removed from the shoal, as measured in bank by the board, was 36,000 cubic yards. The material removed was placed upon the Commonwealth flats at South Boston. The work under this contract was executed in a manner entirely satisfactory to the board, and creditable to the contractors.

The removal of the shoal at East Boston has already proved a most timely aid in the provision of facilities for the increased number of foreign steamers of large draft. The removal was not commenced too soon, nor has it proceeded more rapidly than the actual demands of commerce have required. It has illustrated the great advantage to the harbor of a fund from which expenditure can be made in the intermediate ground between what may be left to individual enterprise and what may be expected from the general government.

## RE-SURVEY OF THE WHARF LINES OF BOSTON UPPER HARBOR.

Since the last Annual Report, the re-survey of Boston Upper Harbor has been continued to a satisfactory completion of the field work within the limits contemplated with the special appropriation provided. There remains some work in the completion of maps and extending soundings, which will be made in connection with the regular office work of the Board, without further special appropriation.

The character and purposes of the re-survey have been indicated in former reports of the Board for 1876 and 1877. Among the essential auxiliaries to the studies and work of the commission are accurate maps and plans, which must be kept up, or renewed from time to time as data from them are required. In providing for this necessity by the present re-survey, the occasion presented an opportunity to establish a system of survey which should secure accuracy in determination, and uniformity in detail, and furnish bases and references which would facilitate and economize the execution of future re-surveys, and at the same time give exact comparison of results. The Board were unanimous in adopting the system of geodetic survey which obtains in the United States Coast Survey. There were no means of securing this result so advantageously as by the co-operation of that department; which was satisfactorily arranged with its superintendent, Hon. C. P. Patterson.

As will be seen by reference to the report of Mr. Francis Blake, jun., assistant in the Coast Survey, in the Appendix, the extent and cost of the triangulation have exceeded the original estimates made for it; but the work has also exceeded the original plan in comprehensiveness, and has furnished bases and data of great present and prospective value. The loss of the triangulation stations of the Coast Survey within the city by the change and rebuilding of spires and conspicuous buildings, and the destruction of markings upon the hills and islands which surround the city, is a proof and admonition of the importance of establishing numerous and securely-marked points of reference, and providing for their protection. As stated in Mr. Blake's report, the main points in the new triangulation have been marked by granite posts

and copper bolts. These stations are upon commanding sites overlooking the city, and include the summits of Blue Hill in Milton, Prospect Hill in Waltham, Powderhorn Hill in Chelsea, Winthrop Head, Breed's Hill, Governor's Island, &c. Besides these points, many spires, cupolas, factory chimneys, &c., have been determined within the city. The total number of points determined by triangulation amounts to 67. The more general knowledge of the existence of these points, their more conspicuous marking, and the frequent future use which will probably be made of them, will tend to their preservation.

The topographical work of the re-survey has been executed by Mr. William E. McClintock, formerly of the United States Coast Survey, and has been under the general supervision of Professor Henry L. Whiting of that department. The instrument used, the "plane table," and the mode of work adopted, are those which are standard in the Coast Survey. The scale and measurements of the re-survey conform to the metric system which obtains in the Coast Survey. The results are given upon a series of twelve original plane-table sheets, which are each about thirty by fifty-two inches in size. Eleven of these sheets are on the scale of  $\frac{1}{10000}$ , and cover the wharf lines of the Upper Harbor, including Fort Point Channel, the South Boston sea walls and dock, the east and north water-face of the city proper, Charles River from the Navy Yard to West Boston Bridge, Chelsea Creek from the Navy Yard to Meridian Street and Chelsea Bridges, with the improvements of the Lowell Railroad Company and the south channel of Mystic River, and the water-face of East Boston as far as it is improved. One sheet, on a scale of  $\frac{1}{20000}$ , includes the shore-lines of Cambridge basin, between West Boston and Brookline Bridges. As stated in the report of Professor Whiting, in the Appendix, upon these sheets are shown all required details along the harbor frontage, with measurements connecting them with the points and corners in the marginal streets, which are also established points in the framework of the city determined by its engineers.

Besides the triangulation and topography, a series of soundings have been made along the city frontage, which show the depth of water in each dock, and at the end of each pier, and beyond the general pier-line, for a distance of 60 feet into the channel.

This work also includes the hydrographical re-survey of Fort Point Channel from Eastern Avenue to Dover Street Bridge. The former harbor surveys have not included these details; and the Board has had no previous reliable data concerning the commercial capacity of the city docks and piers. By a closer degree of economy in the execution of the topographical part of the survey than was at first deemed practicable, the results of this work have nearly if not quite come up to the original project for it, and cover most of the wharf-lines of the Upper Harbor at present utilized in important commerce.

One of the special purposes to which the data of the re-survey will be applied is the study of the harbor lines with a view to a re-statement, or of such re-determination and modification, of the existing lines as their uncertain and defective condition may require. Upon completion of the maps, and a careful study of all the results of the re-survey, the Board expect to present a re-statement of the lines which may be more safely embodied in legislation than any which they are now prepared to propose. As stated in the report of 1876, the present harbor lines were established by various and independent acts of the Legislature, some of them dating back over 40 years. During this lapse of time many of the original reference points have been lost by the obliteration of old landmarks and in the changes occasioned by the erection of new structures, many of which were authorized without due regard to the prescribed harbor boundaries. These changes occurred prior to the establishment of the permanent commission in 1866, since which time no important encroachments have been made.

#### GREEN HARBOR RIVER.

A bill in equity has been brought by the attorney-general, under the provisions of chap. 219 of the Acts of 1877, to compel the parties liable under chap. 303 of the Acts of 1871 to remove the shoaling occasioned in the channel of Green Harbor River. The bill was filed in May last, and is still pending. Nothing has occurred to change the views of the Commissioners expressed in previous reports in relation to the injuries to this harbor arising from the erection of the dike.



## SCITUATE HARBOR.

The condition of Scituate Harbor has enlisted the active interest of the citizens of that town, and of several organizations interested in the safety of vessels approaching Boston; and a strong movement has been made to induce the United States to make an appropriation for the improvement of the entrance. Hon. George Lunt, now a resident of Scituate, has collected and presented much valuable information in relation to the history of the harbor and its use as a port of refuge. A memorial of this Board in aid of the movement has been presented to Congress, a copy of which will be found in the Appendix. Congress has already ordered a survey of the harbor, which has been made under the direction of Gen. Thom of the U. S. Engineer Department.

## STATE SUPERVISION OF HARBORS.

The Commonwealth has always claimed extended rights in, and control over, tide-water. The duties growing out of the rights and control thus claimed have not been denied. The present system of preserving and developing public interests in the harbors of the Commonwealth was of slow growth, from a series of experiments and studies which it may be of use to review briefly in any new study of methods of administration which the depressed condition of business may occasion.

The colony ordinance of 1641 attests early legislative attention to the relation of private and public interests in the sea and lands under tide-water. By that ordinance the rule of common law, which gave to the State exclusive ownership below high water, was so far reversed, that private title was made to extend one hundred rods into the sea from high-water mark, or to low water when not more than that distance. There has been no more radical change in the law affecting this public interest than that caused by the ordinance in question. It complicated the problem of preserving and developing the interests of the public, and has been fruitful in occasion for legislation and in litigation; but it vested rights beyond recall.

Statutes for the protection of the different harbors of the

Commonwealth, and in relation to the erection of structures in tide-water, were frequent from the adoption of the constitution; but the growth of the State, and the increased use of its principal harbors, early induced the Legislature to make use of other agencies to secure more systematic and complete knowledge of the needs of such harbors, and what could be safely permitted in the construction of wharves and other structures therein.

Under a resolve of March 5, 1835, a commission consisting of Loammi Baldwin, S. Thayer, and James Hayward, all engineers of high attainments, was appointed by Gov. Davis "To cause a survey to be taken of such portions of the harbor of Boston as are comprised between Boston South Bridge and the dam of the Boston and Roxbury Mill Corporation, including the wharves and flats of East Boston and of Charlestown; and to define, upon a plan or plans, such lines as they shall think it expedient to establish, beyond which no wharves shall be extended into and over the tide-water of the Commonwealth on either side of said harbor; and report their doings to the Governor and Council. The commission thus appointed occupied nearly two years in the work assigned them; and submitted their report Jan. 30, 1837, in which they state forcible reasons why the full enjoyment of the rights thought to be given by the ordinance of 1641 would be inconsistent with the existence of the harbor. Chap. 229 of the Acts of 1837, establishing a harbor-line for the principal front in Boston Harbor, was based upon the report of this commission; and the line then established has continued without material alteration to the present time, though some of its points have become difficult of location from the destruction or change of structures then used for reference-points. It is believed, however, that when the results of the latest re-survey are fully extended upon the maps, little more will be found necessary than a re-statement of the old line by reference to new monuments more easily ascertained.

Two years later, under a resolve of April 9, 1839, a second commission, consisting of H. A. S. Dearborn, James F. Baldwin, and Caleb Eddy, was appointed to define such further lines upon either side of the harbor of Boston as they should think expedient, beyond which no wharves

should be extended. The report of this commission was one of the most thoughtful and suggestive of the series in which the harbor questions have been presented. Upon its recommendation further harbor-lines were established by chap. 35 of the Acts of 1840.

Five years later, under a resolve of March 22, 1845, a third commission for a similar purpose was appointed, which consisted of James Hayward and Ezra Lincoln, jun. This commission submitted, the year following, a report containing much information in regard to South Bay, Mystic River, and Charles River; and upon its recommendation new harbor-lines were established in those localities by chap. 278 of the Acts of 1847.

A fourth commission, consisting of Joseph Bell and Ezra Lincoln, jun., appointed under a resolve of April 16, 1846, had first examined the legal questions involved in the recommendations of the commission of 1845, and had reported conclusions since fully sustained by the courts.

A fifth commission, consisting of Thomas G. Cary, Simeon Borden, and Ezra Lincoln, was appointed under a resolve of the same date, to examine the flats at South Boston with a view to a plan of improvement thereof beneficial to commerce; and made, Feb. 2, 1847, a careful report, which discussed the probable effect of the reclamation of the flats in question upon the harbor, and advised great caution in relation thereto.

A sixth commission, consisting of Samuel S. Lewis and Ezra Lincoln, jun., was appointed under resolve of April 7, 1847, in relation to a survey of Boston Harbor, and was instructed by an additional resolve, May 10, 1848, to present lines for a harbor-line in Chelsea Creek; also to ascertain whether obstructions were forming in Fort Point Channel, and whether legislation was necessary to prevent or remove the same. In its report, this commission recognize the principle of requiring compensation from those authorized to extend structures into tide-water, and recommend that the proprietors of certain wharves be required to remove the bar in Fort Point Channel as a condition of extending their wharves to a new line.

The seventh commission was appointed under resolve of May 10, 1843, "To consider, and report to the next Legisla-

ture, what are the rights and duties of the Commonwealth in relation to the flats in the harbor of Boston." Other duties were assigned specifically, but the report of the commission treated principally the comprehensive subject committed to it. A brief report was submitted in 1849, signed by Richard Fletcher, David Cummings, George S. Boutwell, and Charles Hudson; and the final report was submitted in January, 1850, signed by John M. Williams, David Cummings, Thomas Hopkinson, George S. Boutwell, and Charles Hudson. Under the head of the rights of the Commonwealth, the legal position was stated with great clearness. In regard to the duties of the State, this commission differed from the conclusions of previous commissions, and advised against the filling of the South Boston flats; predicting that in 50 years the utmost capacity of the harbor would be required, and contending that nothing should be filled which is capable, by excavation, of being converted at a reasonable expense into wet docks or roadsteads.

The eighth commission consisted of Simon Greenleaf, Joel Giles, and Ezra Lincoln, jun., and was appointed under a resolve of May 3, 1850. Its first report is dated March 22, 1851. The legal questions involved in the State's relations to tide-water are again exhaustively discussed in this report; also the expediency of filling the flats at South Boston, and harbor lines in South Bay. A permanent board of trustees or commissioners is recommended. The final report was presented March 11, 1852, in which the establishment of a State commission upon Boston Harbor and its tributary waters was again recommended.

Under resolve of May 20, 1852, probably passed upon the recommendation last cited, a ninth commission was appointed, — the first of a permanent character, — which was termed the Commissioners on Boston Harbor and the Back Bay. The duties of this board seem to have been principally confined to the interests of the Commonwealth in the Back Bay; and in 1855 the name was changed, so that it was afterwards known as the Commissioners on the Back Bay.

Under resolve of April 7, 1854, a tenth commission was appointed, to establish lines in Mystic River, Boston Harbor, and Dorchester Bay. This board consisted of Henry W. Kinsman, Charles Henry Davis, and Edward H. Eldredge.



A partial report was made in December, 1854; and a final report Feb. 28, 1855, in which the commissioners say that the recommendation to which they attach the highest importance is, "that the care and superintendence of the whole harbor and its dependencies, or of all the tide-waters of Massachusetts, be assigned to a permanent board, or some other standing authority;" and again: "They cannot take " "leave of the subject without once more referring to the " "imperative necessity now existing of establishing a perma- " "nent Board of Harbor Commissioners. The conditions " "herein recommended as of the first importance, in connec- " "tion with any improvements which the Legislature may " "hereafter authorize in either of the great tidal reservoirs, " "—the continued building of new wharves, and extension " "of old ones; the filling up of docks and flats to the exclu- " "sion of the tide; the consequent diversion of currents to " "a greater or less degree; the changes which have taken " "place in the channels, and the causes which have pro- " "duced these changes,—all point to the necessity of a " "continued supervision. Much good has resulted from the " "examinations made by the several commissions heretofore " "appointed; but the results, so far as the protection of this " "great public interest is concerned, would undoubtedly " "have been much more beneficial, while the expense would " "not probably have been greater, had a permanent board " "been continued from the year 1835 to the present time. " "It is manifest that every new board of commissioners, and " "every new committee of the Legislature, having the sub- " "ject in charge, must encounter great difficulties from their " "want of previous acquaintance with it. In the liability " "to an entire change from year to year in the formation of " "these bodies is to be found an additional reason, namely, " "that the time occupied in learning the duties of its charge " "is so much lost to the full performance of its functions. " "The experience of one board does not descend to its suc- " "cessors. It should be made the duty of such a commis- " "sion to see that the works allowed to be erected within it " "should do no injury, or the least possible injury, to the " "harbor; that they should be what they were authorized " "to be, and nothing more; that plans should be made of all " "such structures, and careful observations recorded of their "

“effect upon the channels. Accurate surveys of the islands”  
 “and headlands should be made yearly, and the result de-”  
 “lineated upon plans drawn upon a large scale, so as to”  
 “show the comparative abrasions of their soil, one season”  
 “with another, and direct attention to the points most se-”  
 “riously affected by the action of the sea. By this means”  
 “also the formation of shoals and spits, and the changes”  
 “of the current injurious to the main channels of the har-”  
 “bor, would be accurately known and defined. Annual”  
 “reports made by such a commission would communicate”  
 “authentic information, and would gradually become a col-”  
 “lection of great historic and practical value.”

In 1859 the land-office, which had been abolished in 1858, was revived, and the land-agent was given in charge all lands, flats, shores, and rights in tide-waters belonging to the Commonwealth, except the Back-bay lands and other lands then provided for by law; and by the same resolve the Governor and Council were given powers in relation to the permission of structures in tide-water similar to those afterward given to the Harbor Commission. The land-office was again abolished in 1861; and the duties of the land-agent were assigned to the Commissioners on the Back Bay, who were thereafter termed the Commissioners on Public Lands.

In 1856 and 1858 the Legislature passed resolves requesting Congress to direct a scientific survey of Boston Harbor; but the survey was not obtained until the city of Boston supplemented the efforts of the Legislature by an appropriation for expenses connected with the same, when the work was thoroughly executed under the direction of United States officers. The results obtained from the survey thus made have been of great service in all subsequent studies of the harbor, and will continue to be of use as long as the harbor shall require care.

The eleventh commission was appointed under resolves of April 28, 1862, and was termed the Commissioners on the Harbors and Flats of the Commonwealth. Its first report was made Jan. 15, 1863, and signed by F. W. Bird and Horace Gray. A second report, made after the completion of the survey of Boston Harbor, was dated March 22, 1864, and signed by Emory Washburn and Horace Gray, in which the importance of a permanent commission, who should have

in charge the interests of the harbor, was urged. A third report, dated Feb. 24, 1865, transmitted the ninth report of the United States commissioners. A fourth report was made Jan. 16, 1866, signed by S. E. Sewall, George B. Upton, and M. D. Ross, in which the following language is used: "In regard to a general system for the care, improvement, and protection of the harbors, we must recommend, as those who have preceded us as a commission have done, the creation of a permanent board of harbor commissioners, to have the supervision of all the harbors and flats of the State;" and considerable space is given to an explanation of the work which existed for such board.

Chap. 149 of the Acts of 1866 established a board of harbor commissioners, consisting of five persons, to be appointed by the Governor. This commission was reduced in 1877 to three members, but without change of duties or name, and may be properly considered the present system. The board thus established were given the general care and supervision of all the harbors and tide-waters, and of all the flats and lands flowed thereby, within the Commonwealth, except the Back-bay lands so called, with power to make surveys, examinations, and observations in any harbor as they may deem necessary, and to employ competent engineers, clerical and other assistance. They were also authorized to prescribe harbor-lines to be reported for the consideration of the Legislature, and to approve the mode of extending structures below high-water mark. In all cases affecting the harbor of Boston, and in cases affecting other harbors when the board should think it necessary, they were required to ascertain the amount of tide-water displaced by any structure or filling thereafter authorized, and require the parties causing the same to make compensation therefor by excavation or a money equivalent, the money thus obtained to constitute a fund applicable to the protection and improvement of the harbor from which it is collected. They were also authorized, whenever they deemed it necessary, to apply to Congress for appropriations for protecting and improving any harbor in the Commonwealth, and to recommend such State legislation as they deemed necessary for the preservation and improvement of the harbors, and the promotion of the interests of the Commonwealth connected therewith. The powers of the



Board in relation to structures were extended by chap. 236 of the Acts of 1872 and chap. 347 of the Acts of 1874. The care of the property interests of the Commonwealth in South Boston flats was transferred from the Harbor Commission to State agents by chap. 239 of the Acts of 1875. The provisions in relation to compensation for tide-water displaced were modified by chap. 74 of the Acts of 1878.

The present system has existed a little more than twelve years, during which the more important harbors of the Commonwealth have been the subjects of careful study by the Board and its engineers. A large number of structures have been authorized in the harbors of Boston and Gloucester, a considerable number in the harbor of Provincetown, and some in nearly every harbor of the Commonwealth. Special surveys and examinations of permanent value have been made in some of the smaller harbors, as well as in those of greater prominence. The Legislature has been relieved of a large number of matters pertaining to the erection or extension of wharves and other structures, important in the aggregate, but consuming time of the Legislature disproportioned to their importance when considered in detail. In the great commercial port of the Commonwealth, through the expenditures of the United States, the enterprise of the State, and the exertion of individuals stimulated by both, great improvements have been effected; and the harbor is in much better condition than ever before to meet the needs of its growing foreign commerce. The special fund for its protection, derived from assessments for tide-water displaced, already amounts to \$131,460.44, the annual interest of which may be expended under the direction of the Harbor Commissioners for needed improvements. There has been expended from this source, for deepening the inner harbor at points which the United States have not been willing to embrace within any scheme of improvement hitherto projected at the national charge, the sum of \$41,300.17; and the deepening thus effected has been immediately utilized by large steamers engaged in the foreign trade, furnishing convincing proof that the improvement was not in advance of the actual need. The reclamation of the flats at South Boston has proceeded to an extent already productive of much improvement in the channels and anchorage-ground of the harbor, by the dredg-



ing done in filling the twenty-five-acre parcel for the State, and in the partial filling of the fifty acres for the Boston and Albany Railroad Company. The Board anticipate still greater benefit from the reclamation of the flats of the Commonwealth east of those of the railroad company and from the dredging which such reclamation will occasion. The care by a separate Board of the property interest of the State in the lands to be reclaimed has not resulted in any conflict of policy or measures. Concentrated attention to the pecuniary results of the improvement in progress is essential to final success.

The active co-operation of the State has been of great service in obtaining liberal action from the general government, which has appropriated \$1,245,170 since the establishment of the Board of Harbor Commissioners in 1866, for works of improvement in Boston Harbor planned by that Board. A plan illustrating the dredging in the upper harbor by the State and general government will be found in the Appendix. The action of the United States in protecting the islands of the outer harbor could not have been delayed many years without serious consequences. The difficult scientific questions involved in wise regulation and supervision of harbor interests have received the continuous attention of engineers of ripe experience in the special studies required. Much information has been gathered and preserved that will be of use in future studies beyond any present means of measurement. No money expended by the Board has in its judgment brought greater returns than that expended for the service of scientific experts. The work of the Board could never be well done without a considerable expenditure for service of this nature, but some of that which will be necessary will be more properly chargeable to the special fund of the harbor in relation to which it may be required.

#### RECEIVED FROM TIDE-LANDS.

There has been received during the year, from the sale of flats belonging to the Commonwealth required for the extension of structures in tide-water licensed by the Board, the sum of \$11,116.55. This amount does not go to the credit of the compensation-fund, but to the sinking-fund for the redemption of the war-debt. The sum thus secured to the State so far amounts to \$36,349.96.

## HARBOR IMPROVEMENTS BY THE GENERAL GOVERNMENT.

The improvements in the harbors of the Commonwealth during the year by the general government have embraced works in the harbors of Boston, Newburyport, Plymouth, Provincetown, Wareham, and Fall River, also in Taunton River. By the courtesy of Gen. George Thom and Gen. G. K. Warren, the Board are permitted to present extracts from the official reports concerning these works made to the chief engineer of the army, which will be found in the Appendix.

The substantial completion of the removal of sunken rock from the main channel in Boston Harbor is a great gain to the safety and convenience of the entrance. The removal of Man-of-war Shoal is under contract, and one-half the work executed. This Board has long deemed the removal of this shoal important, and in 1877 presented to Congress a memorial urging the action which has been taken.

## OFFICE AND FIELD WORK.

In addition to the usual routine work connected with the ordinary duties of the Board, the re-survey of Boston Harbor has continued to receive considerable time and attention from the engineers. The number of licenses granted during the year has been about the same as in previous years, a list of which is given below. Fewer controversies have arisen in relation to structures authorized than heretofore.

*Plans approved by the Board of Harbor Commissioners during the year 1877, for the erection of structures in or over tide-water, and licenses granted for such structures.*

Nos.

407. Boston and Hingham Steamboat Company, for leave to extend its wharf in Hingham Harbor on piles. Approved March 20, 1878.
408. Onset Bay Grove Association, for leave to build a pile wharf in Onset Bay, town of Wareham. Approved Feb. 27, 1878.
409. City of Boston, for leave to rebuild the southerly draw-pier of Cambridge Street Bridge over Charles River. Approved March 6, 1878.
410. Nathaniel E. Atwood of Provincetown, for leave to extend his wharf in Provincetown Harbor on piles. Approved March 6, 1878.

411. J. F. Small of Provincetown, for leave to build a pile wharf in Provincetown Harbor. Approved March 20, 1878.
412. Benjamin Lancy of Provincetown, for leave to extend his wharf in Provincetown Harbor on piles. Approved March 20, 1878.
413. R. G. Tarrant of Provincetown, for leave to construct a pile wharf in Provincetown Harbor. Approved March 20, 1878.
414. Boston and Hingham Steamboat Company, for leave to construct a pile wharf on Weir River at Nantasket Beach in the town of Hull. Approved March 20, 1878.
415. City of Boston, for leave to build a foundation for an office and stable on piles, for Meridian Street Bridge. Approved March 27, 1878.
416. City of Salem, for leave to widen and repair the draw in Essex Bridge over the river between Salem and Beverly. Approved April 3, 1878.
417. Stone & Downer, for the construction of a breakwater at Nye's Neck, near the entrance of Wild Harbor, town of Falmouth. Approved April 3, 1878.
418. Boston and Lowell Railroad Corporation, for leave to widen its freight-bridge over Charles River. Approved April 17, 1878.
419. Fitchburg Railroad Company, for leave to widen its bridge over Charles River on the north side. Approved April 24, 1878.
420. Fitchburg Railroad Company, for leave to widen the northerly pier of Constitution Wharf on piles. Approved April 24, 1878.
421. T. A. Newhall of Lynn, for leave to extend his wharf in Lynn Harbor by solid filling. Approved May 22, 1878.
422. Boston, Clinton, Fitchburg, and New Bedford Railroad Company, for leave to extend its wharf in New Bedford Harbor. Approved May 22, 1878.
423. Boston, Revere Beach, and Lynn Railroad Company, for the construction of a pile wharf and ferry-slip between Rowe's and Foster's Wharves, Boston. Approved May 22, 1878.
424. Boston, Revere Beach, and Lynn Railroad Company, for the construction of a pile wharf and ferry-slip at East Boston. Approved May 22, 1878.
425. Alden Choate of Lynn, and Jonathan Blaney and others of Swampscot, for leave to extend their wharf by solid filling, and dredge a channel in front of said wharf, in Lynn Harbor. Approved May 29, 1878.
426. Fenno Tudor of Nahant, for the extension of Central Wharf on piles in the town of Nahant. Approved May 29, 1878.
427. Boston and Albany Railroad Company, for leave to rebuild the draw in its bridge over Chelsea Creek. Approved May 29, 1878.
428. Town of Revere, for leave to fill solid Boatfield Bridge across Sales Creek. Approved June 19, 1878.
429. New York and New England Railroad Company, for leave to widen its bridge across Fort Point Channel, and fill up a dock between its property and what was formerly Drake's Wharf. Approved July 10, 1878.

430. Haskins Brothers, for the extension of their wharf on Maverick Street, East Boston. Approved July 17, 1878.
431. City of Cambridge, for leave to construct a retaining-wall on the easterly abutment of River Street Bridge. Approved July 1, 1878.
432. Samuel Q. Currier, for leave to build a sea-wall in Hingham Bay, town of Hull. Approved Sept. 4, 1878.
433. Kidder, Vaughan, & Co., for leave to build a wharf, partly solid and partly on piles, in Chelsea Creek, East Boston. Approved Sept. 11, 1878.
434. Daniel B. Gardner and others, for leave to construct a dam across the mouth of Juniper Point Cove, Salem Harbor. Approved Oct. 30, 1878.
435. Maverick Oil Company, for leave to fill flats, and enclose the same by a sea-wall, in Chelsea Creek, East Boston. Approved Sept. 25, 1878.
436. Nehemiah Lee, for leave to extend his wharf and excavate a channel therefrom, in Lynn Harbor. Approved Oct. 2, 1878.
437. Eben Wright, for the construction of a solid wharf at Cohasset Narrows in the town of Sandwich. Approved Oct. 9, 1878.
438. Plans and specifications for the construction of platforms in Fort Point Channel and the State Dock at South Boston, and for fenders upon heavy sea-walls upon the Harbor. Approved Aug. 30, 1878.
439. The same.
440. The same.
441. Andrew C. Wheelwright, for the construction of a pile-wharf in Cohasset Harbor. Approved Oct. 17, 1878.
442. J. W. White, for leave to build a stone wall and wharf in Marblehead Harbor. Approved Oct. 17, 1878.
443. Mercantile and Commercial Wharf Corporations, for leave to drive piles between their piers for the foundation of storehouses. Approved Oct. 23, 1878.
280. Boston, Revere Beach, and Lynn Railroad Company, for leave to fill solid the bridges on the line of its location between its depot at Lynn and Saugus River. Approved Oct. 23, 1878.
444. Central Wharf and Wet Dock Corporation, for leave to widen its wharf in Boston Harbor. Approved Oct. 30, 1878.
445. Stephen N. Breed, for leave to fill up a portion of his dock in Lynn Harbor. Approved Nov. 6, 1878.
446. George H. and John Cavanagh, for leave to build a road from Dorchester Avenue to "Wales Island," South Bay. Approved Nov. 6, 1878.
447. Hiram Harding and others, for leave to build a pile wharf at Stage Harbor, Chatham. Approved Nov. 6, 1878.
448. David P. Davis, for leave to extend his wharf on piles in Taunton River, town of Somerset. Approved Nov. 13, 1878.
449. Mount Hope Iron Company of Somerset, for the extension of their wharf by solid filling in Taunton River. Approved Nov. 20, 1878.
450. Fitchburg Railroad Company, for leave to straighten the end of Constitution Wharf, Boston Harbor. Approved Dec. 4, 1878.



The Board continues under obligations to Hon. C. P. Patterson, Superintendent of the United States Coast Survey, and to Generals Thom and Warren of the Engineer Department, for courteous assistance given in their work.

During the year Professor Peirce and Professor Mitchell have resigned their positions as members of the United States Advisory Council. The Board has been much indebted to these officers in the past; and, although Professor Peirce has been less frequently consulted for the latter portion of his service, the privilege of obtaining his opinion when needed was highly esteemed. Professor Mitchell's duties on the United States Coast Survey enabled him to be with the Board a larger portion of his time than any other member of the Advisory Council could give to the work; and the Board has derived from his service assistance of very great value. It is hoped that as future occasion shall arise, the Board will be able to obtain again the counsel and assistance of these eminent authorities. Professor Henry L. Whiting of the United States Coast Survey has continued to render the Board valuable service.

FREDERIC W. LINCOLN.  
FRANCIS A. NYE.  
ALBERT MASON.

BOSTON, Dec. 30, 1878.



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# APPENDIX.

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[A.]

## IMPROVEMENT OF SOUTH BOSTON FLATS.

RECORD OF POINTS AND LINES DEFINING THE "TWENTY-  
FIVE-ACRE PIECE," IMPROVED BY THE STATE IN  
1873-7, AND ADJOINING FLATS.

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MAY, 1878.

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TABLE I.

POINT.	Ordinate.	Abscissa.	Angle at C right from P to point.	Angle at P G left from C to point.	Angle at C right from $\delta$ to point.	Angle at $\delta$ left from C to point.	Distance from C to point.	Angle at C' right from C to point.	Distance from C' to point.
	Feet.	Feet.	° ' "	° ' "	° ' "	° ' "	Feet.	° ' "	Feet.
P	0.	0.	0	0	0	0	0	0	0
P C	0.	0.	-	-	-	-	-	-	-
C	0.	910.	-	-	-	-	-	-	-
R	+ 893.334	736.641	-	-	-	-	-	-	-
Y	+ 934.823	1092.890	-	-	-	-	-	-	-
T	+ 911.565	1532.609	-	-	-	-	-	-	-
S	+ 848.043	1964.968	-	-	-	-	-	-	-
O	- 1932.380	1962.391	-	-	-	-	-	-	-
N	- 1932.380	1248.391	-	-	-	-	-	-	-
M	- 1247.380	1248.391	-	-	-	-	-	-	-
L	- 1253.970	1092.030	-	-	-	-	-	-	-
K	- 1300.000	0.	-	-	-	-	-	-	-
X	- 312.500	0.	-	-	-	-	-	-	-
Z	- 396.079	1089.801	-	-	-	-	-	-	-
U	+ 929.062	997.548	-	-	-	-	-	-	-
V	- 388.768	994.471	-	-	-	-	-	-	-
C'	- 1433.262	1188.135	-	-	-	-	-	-	-
$\alpha$	- 314.782	29.800	-	-	-	-	-	-	-
$\beta$	- 314.642	27.976	-	-	-	-	-	-	-
$\gamma$	0.	29.800	-	-	-	-	-	-	-
A	+ 870.295	667.146	74 24 30	54 39 31.25	28 56 57.576	09 17.5	903.544	-	-
B	+ 616.407	683.359	69 48 45	44 13 22.5	35 26 12.574	27 55	656.753	-	-
D	- 48.874	687.639	12 23 50	-	-	-	227.65 ...	-	-
F	+ 45.714	860.133	42 30 45	-	-	-	67.65 ...	-	-
G	+ 615.813	868.408	86 08 10	36 57 35	-	-	617.216	-	-
H	+ 912.133	892.685	88 54 45	-	-	-	912.298	-	-
$\epsilon$	+ 925.387	997.540	95 24 00	-	-	-	929.512	-	-





TABLE I. — Concluded.

POINT.	Ordinate.	Abscissa.	Angle at C right from P to point.	Angle at PC left from C to point.	Angle at C right from $\delta$ to point.	Angle at $\delta$ left from C to point.	Distance from C to point.	Angle at C' right from C to point.	Distance from C' to point.
1.5 feet back from Front Top Line of Caps — East End of Heavy Wall East of Dock . . . . .	Feet. +929.490	Feet. 1043.620	° ' " 98 10 50	° ' " —	° ' " 38 13 02.573	° ' " 44 50	Feet. 939.045	° ' " 7 28 55.5	Feet. 2367.167
Intersection of Front Top Line of Caps of B. & A. Dock Wall with Back Top Line of Heavy Wall East of Dock . . . . .	+924.442	1016.837	96 35 32.5	—	36 37 45	73 53 37.5	930.594	6 30 03.5	2363.918

*Rectangular Coördinates.* — Ordinates are from line through origin and centre of curve of 910 feet radius, and are marked + when northerly and — when southerly.  
Abscissas are easterly from tangent in Commissioners' line at origin of coördinates.

TABLE. II.

LINE.	LENGTH OF		Angle between line or chord and Com- missioners' line tangent at P.	S. Feet.	C. Feet.	Radius. Feet.	Angle at Centre.
	Line or Arc. Feet.	Chord. Feet.					
P-E	(1) 1,255.	1,157.80	° 38 - 30 - 32.05	736.641	893.354	(1) 910.	° 79 - 01 - 04.10
PC-POC	1,186.044	—	do.	—	—	860.	do.
P-Y	(1) 1,614.	—	° 88 - 41 - 16.71	795.968	18.251	(1) 2,370.	° 19 - 20 - 25.23
R-T	(1) 800.	796.207	° 83 - 21 - 26.27	356.249	—	—	—
Y-S	(3) 878.	—	° 98 - 21 - 29.33	432.358	63.522	(1) 2,370.	° 8 - 40 - 44.33
R-Y	359.	358.657	—	2.574	2,780.483	—	—
T-S	437.	—	(2) 90	714.	0.	—	—
S-O	2,780.484	—	(3) 0	0.	685.	—	—
O-N	(3) 714.	—	° 87 - 35 - 11	156.361	6.591	—	—
N-M	(3) 685.	—	do.	1,092.030	46.029	—	—
M-L	(3) 156.5	—	° 0	0.	1,300.	—	—
L-K	(2) 1,093.	—	° 0	0.	987.5	—	—
P-K	(1) 1,300.	—	° 0	0.	312.5	—	—
K-X	987.5	—	° 130 - 46 - 02	1,092.033	—	—	—
X-P	(2) 312.5	—	° 41 - 13 - 28.05	1,092.890	941.523	—	—
X-L	1,441.874	—	° 94 - 22 - 48	2.229	1,247.323	—	—
X-Y	1,658.379	—	do.	1,089.801	857.892	—	—
X-Z	(2) 858.	—	° 0 - 07 - 58.5	994.471	83.579	—	—
X-Z	(2) 1,093.	—	° 0 - 07 - 58.5	3.088	76.268	—	—
X-V	997.390	—	° 0 - 07 - 58.5	—	1,330.902	(1) 2,370.	° 6 - 22 - 10.5
Y-Z	1,330.906	263.380	° 0 - 07 - 58.5	3.076	—	—	—
R-U	263.477	—	° 94 - 22 - 48	95.330	1,317.830	—	—
U-V	1,317.830	—	° 90	50.	7.310	—	—
V-Z	95.610	—	° 90	860.	0.	—	—
P-PC	50.	—	° 169 - 01 - 04.10	451.494	2,326.597	—	—
PC-C	860.	—	° 87 - 35 - 11	—	—	—	—
R-C'	(1) 2,370.	—	do.	—	—	—	—
K-W	83.8	—	—	—	—	—	—
W-E	922.	—	—	—	—	—	—

TABLE II. — Continued.

LINE.	LENGTH OF		Angle between line or chord and Com- missioners' line tangent at P.	S. Feet.	C. Feet.	Radius, Feet.	Angle at Centre.
	Line or Arc. Feet.	Chord Feet.					
K-C	1,586.852	-	0   '   "	910.	1,300.	-	-
A-B	254.405	-	-	16,213	253,888	-	-
B-D	567.549	-	-	4,300	567,533	-	-
D-F	172.503	-	-	172,474	3,160	-	-
F-G	370.158	-	-	8,275	570,099	-	-
G-H	297.313	-	-	24,277	296,320	-	-
E-L	87.2	-	87 - 35 - 11	-	-	-	-
SM-E	380.14	-	63 - 01 - 04	-	-	-	-

Angle C-PC-W =  $88^{\circ} 30' 22''$   
 "     PC-W-E =  $89^{\circ} 04' 49''$

S = product of length of line by the sine of the angle made by it with the Commissioners' line tangent at P.  
 C = product of length of line by the cosine of the angle made by it with the Commissioners' line tangent at P.

(1) See Second Report of Harbor Commissioners, p. 8.

(2) See Fourth Report of Harbor Commissioners, p. 70.

(3) See Fourth Report of Harbor Commissioners, p. 100.



## DESCRIPTION OF POINTS IN TABLES.

- a* Copper bolt on Boston Wharf Company's line, in top of most southerly cap of Fort Point Channel light wall, 1.7 feet back from front, and about 0.4 feet from south side of said cap.
- β* Copper bolt on Boston Wharf Company's line, in second face-stone under most southerly cap of Fort Point Channel light wall, and 1.83 feet out from *a*.
- γ* Copper bolt 2.15 feet back from front top line of caps of Fort Point Channel light wall, at south end of curve.
- δ* Copper bolt 1.5 feet back from front top line of caps of heavy wall west of dock, and 557.2 feet from west end of said wall, in range with No. 9 dolphin and C.
- ε* Copper bolt 2.5 feet back from front top line of caps of heavy wall east of dock, 46.12 feet from east end of said wall. This bolt is on Boston and Albany Railroad Company's line, provided a strip 95.33 feet in width (containing 126,280 square feet) is set off to said company from old boundary, as proposed.
- V Copper bolt in the top of stone monument 8 inches square, set 5 feet in the ground. It is on the line of the Boston Wharf Company, and is on the line of the Boston and Albany Railroad Company also, provided a strip 95.33 feet in width (containing 126,280 square feet) is set off as proposed.
- C Copper tack in the top of a wooden post 6 inches square, set 8 feet in the ground. It is at the centre of the curve of 910 feet radius in the Commissioners' line, and is 67.75 feet from south-east corner of State dock-wall.
- C' Centre of curve of 2,370 feet radius, not fixed on the ground.
- PC Copper tack in the top of a wooden post 6 inches square, set four feet in the ground. It is at the P.C. (beginning) of curve of 860 feet radius, and 22.35 feet back from front top line of caps of Fort Point Channel light wall.
- E Copper tack in the top of a pile of an old bulkhead on Commissioners' line A.\* It is 87.2 feet westerly from L.
- W Copper tack in the top of an oak plug about 15 inches long, driven into the ground flush with its top. It is 922 feet from E on Commissioners' line A,\* and about 80.3 feet from front of wooden wharf, and about in range with the top front line of a jog of 10 feet in Channel wall.
- R Tangent point of both the curve of 910 feet radius and the curve of 2,370 feet radius in the Commissioners' line.
- U Intersection of the line through *ε* and V with the Commissioners' line.
- Y Original north-east corner of the "twenty-five-acre piece" of State flats before setting off a strip from it to the Boston and Albany Railroad Company.
- T East end of the curve of 2,370 feet radius in the Commissioners' line.
- Z North-east corner of the Boston Wharf Company's flats and the original south-east corner of the "twenty-five-acre piece" of State flats.
- X South-west corner of the "twenty-five-acre piece," and north-west corner of the Boston Wharf Company's flats. On Commissioners' line along Fort Point Channel.
- K Intersection of Commissioners' line A\* with the Commissioners' line on the east side of Fort Point Channel.

\* Commissioners' line A as fixed on ground by Harbor Commissioners in 1873.

SM Point 0.29 feet south and 0.04 feet east of a copper bolt in stone monument. It is on the range of the west side of A Street in South Boston, and is 380.14 feet from E.

P Origin of co-ordinates and beginning of curve of 910 feet radius in Commissioners' line.

\* A Intersection of the back† top line of caps of the heavy wall west of dock with the prolongation of the front top line of caps of the straight part of the west dock-wall between the angle point and the heavy wall.

\* B Front top line of caps at the angle point in the west dock-wall.

D Intersection of the front top line of caps of the west dock-wall with the front top line of caps of the end dock-wall.

F Intersection of the front top line of caps of the end dock-wall with the front top line of caps of the east dock-wall.

\* G Front top line of caps at the angle point in the east dock-wall.

\* H Intersection of the front top line of caps of the east dock-wall with the back† top line of caps of the heavy wall east of dock.

See accompanying sketch for location of points in tables.

Measurements were made with a steel tape, and were corrected for temperature, &c., so as to agree with the Boston City Hall standard.

\* Marked by crowfoot (†) cut in wall.

† Back top line of caps of heavy wall is 5 feet back from front line.

[B.]

REPORT ON TRIANGULATION CONNECTED WITH THE  
RE-SURVEY OF BOSTON UPPER HARBOR FOR THE  
MASSACHUSETTS BOARD OF HARBOR COMMISSIONERS.  
1877-78.

---

By FRANCIS BLAKE, JUN., ASSISTANT U.S. COAST SURVEY.

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BOSTON, MASS., March, 1878.

MR. C. P. PATTERSON, *Superintendent United States Coast Survey.*

Sir, — By an Act of the Massachusetts Legislature of 1877, an appropriation for the re-survey of Boston Upper Harbor was made, to be expended under the direction of the honorable Board of Harbor Commissioners of the Commonwealth.

In September last, in response to a request of the Board, you were pleased to instruct me to execute the triangulation connected with this re-survey; and I now have the honor of making a final report on its execution, and of transmitting to you its records, computations, and final results.

Your instructions, dated Tuesday, Sept. 11, 1877, were received the following Thursday; and the next day I placed my services at the disposal of the Board. They expressed the wish that I should at once begin such a triangulation as would establish a large number of initial points for the topographical survey, and assigned Messrs. William E. McClintock and H. Raeder to act as my assistant and recorder, respectively, during the work. Mr. McClintock had already been engaged for several weeks in erecting signals, and searching for some old established Coast Survey points from which the triangulation might be started. In this search he had succeeded in identifying but one point in the vicinity of our work, which had been occupied during the original triangulation of the harbor. This point was Blind Asylum Cupola, South Boston; and a reference to the old scheme showed that a line thence to Powderhorn Chelsea, would best serve as a base from which to start our work. But all traces of the latter station had been obliterated during the construction of a road across the summit of the hill from which it derives its name. Arrangements were made, therefore, to determine at once a new station on Powderhorn Hill from the old Coast Survey base, Blue Hill to Prospect Waltham. Tripod signals were erected at the points of this main triangle; but, by the time we received a suitable instrument for the angular measurements, the smoke of the city, which had been rapidly increasing with the advance of the season, had become so dense, that, even on the clearest days, the

signals were not well enough defined to be observed upon. However, Mr. McClintock, with commendable ingenuity and at a trifling expense, devised and constructed two heliotropes, with the aid of which this first step in our work was brought to a satisfactory conclusion. About 150 measurements were made to determine the angle at each station; the probable errors of the finally adopted values being  $0''.32$  at Blue Hill,  $0''.23$  at Prospect Waltham, and  $0''.46$  at Powderhorn.

The following data with reference to the base, Blue Hill to Prospect Waltham, were promptly furnished, at my request, by Professor J. E. Hilgard, assistant in charge of the Coast Survey office:—

Blue Hill, Latitude  $42^{\circ} 12' 41''.900$ . Longitude  $71^{\circ} 6' 31''.630$ .  
 Prospect Waltham, Latitude  $42^{\circ} 23' 16''.842$ . Longitude  $71^{\circ} 14' 54''.393$ .  
 Blue Hill to Prospect Waltham,  $K = 22722.78$  meters.  
 Blue Hill to Prospect Waltham,  $Z = 149^{\circ} 35' 57''.8$ .  
 Prospect Waltham, to Blue Hill,  $Z = 329^{\circ} 30' 19''.4$ .

These data, in connection with our observations, give the following geodetic position of Powderhorn (1877):—

Latitude  $42^{\circ} 24' 2''.589$ .  
 Longitude  $71^{\circ} 1' 30''.999$ .

The old established geodetic position of Blind Asylum, also furnished by Professor Hilgard, is:—

Latitude  $42^{\circ} 20' 5''.055$ .  
 Longitude  $71^{\circ} 2' 11''.795$ .

By working our L M Z formula backward, the length and azimuths of the line joining these points have been deduced as follows:—

Powderhorn (1877) to Blind Asylum,  $K = 7387.68$  meters.  
 Powderhorn (1877) to Blind Asylum,  $Z = 7^{\circ} 15' 42''.7$ .  
 Blind Asylum to Powderhorn (1877),  $Z = 187^{\circ} 15' 15''.2$ .

This is the base from which the subsequent triangulation is derived.

It should be noted that the work up to this point was entirely unforeseen at the time the original estimate was made of the cost of the triangulation connected with the re-survey of the wharf lines of Boston Upper Harbor. [*Vide* "Eleventh Annual Report of the Board of Harbor Commissioners," p. 17.] It was then believed that the triangulation could be started directly from a base in the immediate vicinity of the work; but the impracticability of the plan, owing to the destruction of the old station-marks, has already been shown.

The above-mentioned base having been established, the subsidiary triangulation for the determination of topographical points was begun, and the field-work diligently prosecuted whenever the weather allowed. During the progress of this work, the idea occurred to me of carefully



determining and permanently marking a number of points, without the city limits, so selected that the lines joining them should form a series of bases, from which any future changes in the harbor lines could be at once referred to the topographical survey. I therefore addressed the following letter to the Board :—

BOSTON, MASS., Oct. 23, 1877.

*To the Honorable Board of Harbor Commissioners of the Commonwealth of Massachusetts.*

GENTLEMEN, — I beg leave to call your attention to the importance of permanently marking a number of the principal stations occupied during the geodetic work upon which I am engaged under your direction. Many of the points determined are selected with special reference to aiding the topographer in his plane-table survey, and will cease to be of extraordinary value when that survey is finished. For these points a temporary marking—as a wooden stub with nail in centre—is therefore sufficient. But it seems to be of great importance that such a series of points should be permanently marked as will enable any future changes in the harbor-lines to be at once, at a trifling expense, referred to the survey now in progress. In selecting these points, due weight must be given to the probability of the land in their vicinity remaining undisturbed; and for marking them I would suggest granite posts, six inches square and five feet long, dressed six inches at the top, and a copper bolt inserted in drill-hole at centre. Such posts can be delivered at the different stations at an average cost of five dollars and fifty cents each. They should be set in the ground, with their tops six inches above the surface. There are not more than fifteen stations which should be so marked.

Very respectfully yours,

FRANCIS BLAKE, JUN., *Assistant U.S.C.S.*

At their next meeting, the Board were pleased to approve the plan proposed in the above letter, and further requested that the letters U.S.C.S. should be cut on the upper faces of the stone monuments mentioned therein.

Eight points were determined and marked in accordance with this approved plan. Their geodetic positions, — determined as directly as possible from the original base, Powderhorn (1877) to Blind Asylum, — and the corresponding lengths and azimuths of the connecting lines, which may be used as bases for future surveys, are given in the following tables.

STATION.	Latitude.			Longitude.		
	°	'	"	°	'	"
Winthrop Head . . . . .	42	22	2.400	70	57	47.182
Breed's Island . . . . .	42	23	26.070	71	0	9.218
Governor's Island . . . . .	42	21	6.860	71	0	20.051
Powderhorn . . . . .	42	24	2.589	71	1	30.999
East Boston Reservoir . . . . .	42	22	50.579	71	1	48.835
South Boston Sea Wall . . . . .	42	21	16.428	71	2	22.410
Naval Hospital . . . . .	42	23	20.616	71	2	34.886
Prospect Somerville . . . . .	42	22	52.639	71	5	16.856

BASE.	AZIMUTH.						Length of Base in Meters.
	Fore.			Back.			
	°	'	''	°	'	''	
Winthrop Head to Governor's Isl'd,	63	54	54.4	243	53	11.4	3,895.01
“ “ to E. B. Reservoir,	105	4	21.9	285	1	39.0	5,724.44
“ “ to Naval Hospital,	110	9	49.1	290	6	35.2	7,009.60
“ “ to Powderhorn .	125	56	19.4	305	53	48.5	6,321.16
“ “ to Breed's Island .	128	28	53.7	308	27	18.0	4,149.66
Breed's Island to Governor's Isl'd.	3	18	12.0	183	18	4.7	4,302.09
“ “ to E. B. Reservoir .	64	20	27.6	244	19	20.4	2,527.81
“ “ to Powderhorn .	121	4	20.2	301	3	25.1	2,183.19
Governor's Isl'd to S. B. Sea Wall .	96	1	41.9	276	0	19.5	2,815.54
“ “ to Naval Hospital .	143	13	55.7	323	12	24.8	5,152.23
“ “ to E. B. Reservoir,	147	36	10.0	327	35	10.2	3,790.23
“ “ to Powderhorn .	163	20	30.1	343	19	42.3	5,659.37
Powderhorn to E. B. Reservoir .	10	24	25.8	190	24	13.8	2,258.63
“ “ to Naval Hospital .	48	27	16.2	228	26	33.1	1,952.35
“ “ to Prospect Som'ville,	67	20	43.6	247	18	11.3	5,598.05
E. B. Reservoir to Naval Hospital .	131	20	20.7	311	19	49.7	1,402.81
Naval Hospital to Prospect Somer- ville . . . . .	76	53	53.1	256	52	3.9	3,803.70

Reference to the computations accompanying this report will show that there are many subsidiary lines, connecting the permanent stations of the preceding tables with stations upon prominent buildings within the city, which may well be used as bases for future surveys, provided the buildings are not destroyed. Of such lines, the more important are those leading to State Street Block,<sup>1</sup> Fitchburg Depot, and Waverley House Charleston.

The geodetic positions of these stations, and the lengths and azimuths of the bases derived from them, are given in the following tables : —

STATION.	Latitude.			Longitude.		
	°	'	"	°	'	"
State Street . . . . .	42	21	31.660	71	2	47.056
Fitchburg Depot . . . . .	42	21	58.386	71	3	20.584
Waverley House . . . . .	42	22	15.579	71	3	25.378

BASE.	Azimuth.						Length of Base in Meters.
	Fore.			Back.			
	°	'	"	°	'	"	
State Street to Governor's Island .	282	48	1.0	102	49	40.0	3,449.83
“ “ to Powderhorn . .	200	28	44.9	20	29	36.2	4,970.92
“ “ to S. B. Sea Wall .	129	48	19.6	309	48	3.0	734.06
“ “ to Naval Hospital .	184	43	47.1	4	43	55.3	3,372.97
“ “ to Waverley House .	147	5	50.5	327	5	24.7	1,613.91
Fitchburg Depot to Powderhorn .	213	10	42.2	33	11	56.1	4,578.89
“ “ to Naval Hospital	202	23	7.7	22	23	38.5	2,743.82
“ “ to Waverley H'se,	168	17	57.8	348	17	54.6	541.69
Waverley House to Naval Hospital,	209	55	2.0	29	55	36.0	2,315.10
“ “ to Prospect Som- erville . .	114	9	31.6	294	8	16.5	2,794.66

The preceding tables present, in a convenient form, the data necessary for any future extension of the harbor-survey, or for the ready reference to the Coast Survey triangulation of work done by the local engineers of many of the towns in the vicinity of Boston. Points in Cambridge, Somerville, Malden, Everett, Revere, Chelsea, Winthrop, Lynn, or Nahant, can be determined directly from one or more of the permanently marked bases. An exact description of the position of each station is given in the volume of the original records of the triangulation, labelled “Descriptions of Stations;” and a copy of this volume may be referred to at any time, on application to the engineer of the Board of Harbor Commissioners.

In the following tables the results of the triangulation are presented in the form which will best serve topographers in the execution of plane table surveys. The relative positions of all points are shown in the sketch of the triangulation appended to this report. Information as to the location of each point may be found in the volume of “Descriptions of Stations” above mentioned.<sup>2</sup>

<sup>1</sup> Written “State Street” in the records and computations.

<sup>2</sup> For additional tables, see end of this Report.

UNITED STATES COAST SURVEY — *Geographical Positions.*

NAME OF STATION.	Latitude.		D.M.	Longitude.		DP.	Azimuth.		Back Azimuth.		TO STATION.	Distance.	Logarithms.
	°	'	"	°	'	"	°	'	°	'	"	Meters.	
Powderhorn (1877)	42	24	2.589	71	1	30.999	85 18	40 10	56.1 43.9	265 198	31 7	54.4 21.6	4 2054473 4 3443980
Blind Asylum	42	20	5.055	71	2	11.795	187	15	15.2	7	15	42.7	3.8985079
Winthrop Head (1877)	42	22	2.400	70	57	47.182	125 59	56 9	19.4 5.0	305 239	53 6	48.5 6.7	3.8007971 3.8485112
Governor's Island (1877)	42	21	6.860	71	0	20.051	163 243	20 53	30.1 11.4	343 63	19 54	42.3 54.4	3.7527678 3.5905085
Breed's Island	42	23	26.070	71	0	9.218	3 308	18 27	12.0 18.0	183 128	18 28	4.7 53.7	3.6336794 3.6180127
E. Boston Reservoir (1877)	42	22	50.579	71	1	48.835	5 285	52 1	33.5 39.0	185 105	52 4	18.0 21.9	3.7104325 3.7577328
East Boston Elevator.	42	21	45.617	71	1	54.450	187 264	13 44	53.1 51.0	7 84	14 47	8.9 37.6	3.6293921 3.7544223
Prospect Somerville	42	22	52.639	71	5	16.856	247 294	18 2	11.3 42.0	67 114	20 43.6	43.6 58.4	3.7480366 3.7051071
State Street	42	21	31.660	71	2	47.056	200 282	28 48	44.9 1.0	20 102	29 49	36.2 40.0	3.6964363 3.5377974
Naval Hospital	42	23	20.616	71	2	34.886	354 290	59 6	35.8 35.2	174 110	59 9	51.4 49.1	3.7822260 3.8156329
Fitchburg Depot	42	21	58.386	71	3	20.584	213 281	10 17	42.2 50.2	33 101	11 18	56.1 48.2	3.6607602 3.3031315



Lowell Round House . . .	42	22	7.757	239.4	71	4	2.327	53.2	{	224	19	5.1	44	20	47.1	Powderhorn (1877)	4,952.94	3.6948627
									{	283	7	46.1	103	9	12.3	East Boston Elevator .	3,004.44	3.4777642
Waverley House . . .	42	22	15.579	480.7	71	3	25.378	580.6	{	74	4	17.9	254	3	53.0	Lowell Round House .	879.02	2.9440006
									{	327	5	24.7	137	5	50.5	State Street . . .	1,613.91	3.2078805
Organ Factory . . .	42	21	42.466	1310.1	71	4	37.130	849.7	{	157	13	40.1	337	13	13.3	Prospect Somerville .	2,347.91	3.3706817
									{	238	5	53.0	58	6	41.3	Waverley House .	1,933.39	3.2863184
Nealy's House . . .	42	21	20.370	628.4	71	6	6.110	139.8	{	201	35	24.6	21	35	57.8	Prospect Somerville .	3,001.51	3.4859304
									{	251	28	41.2	71	29	41.2	Organ Factory . . .	2,147.18	3.3318686
Otter Street . . .	42	21	19.479	601.0	71	4	3.851	88.1	{	132	58	2.0	312	57	39.6	Organ Factory . . .	1,040.58	3.0172756
									{	181	20	22.9	1	20	23.9	Lowell Round House .	1,490.00	3.1731876
South Boston Sea wall .	42	21	16.428	506.8	71	2	22.410	512.8	{	353	42	10.7	173	42	17.9	Blind Asylum .	2,215.42	3.3454571
									{	276	0	19.5	96	1	41.9	Governor's Isl'd (1877)	2,815.54	3.4405615
Sugar Refinery . . .	42	20	42.018	1296.3	71	2	54.512	1247.8	{	215	0	19.6	35	1	0.1	East Boston Elevator .	2,395.77	3.3794446
									{	319	23	22.3	139	23	51.1	Blind Asylum . .	1,502.18	3.1767211
Gray's Wharf . . .	42	22	7.511	231.8	71	2	55.321	1265.7	{	64	1	41.7	244	1	24.7	Fitchburg Depot	642.81	2.8080829
									{	109	53	58.9	289	53	38.6	Waverley House .	731.37	2.8641392
Prince Street Draw . .	42	22	5.813	179.4	71	3	14.856	239.9	{	29	44	56.9	209	44	53.0	Fitchburg Depot	263.93	2.4214817
									{	141	22	1.7	321	21	54.6	Waverley House .	385.70	2.5862525
Gambrell Roof . . .	42	22	16.402	506.0	71	3	5.395	123.4	{	32	0	26.8	212	0	16.6	Fitchburg Depot	635.45	2.8165425
									{	86	49	27.1	266	49	13.6	Waverley House .	457.94	2.6608697
Tudor Cupola . . .	42	22	13.003	401.2	71	3	18.760	429.2	{	5	16	34.8	185	16	33.6	Fitchburg Depot	432.89	2.6559902
									{	117	40	45.6	297	40	41.1	Waverley House .	171.08	2.2331883
Fitchburg Round House .	42	22	21.448	661.7	71	3	48.969	1120.3	{	317	36	26.6	137	36	45.8	Fitchburg Depot	963.35	2.9837826
									{	288	32	52.4	108	33	8.3	Waverley House .	569.16	2.7552312
Pole on red one-story building.	42	22	5.948	183.6	71	3	56.336	1288.9	{	285	54	56.2	105	55	20.3	Fitchburg Depot	850.67	2.9297606
									{	247	14	9.9	67	14	30.8	Waverley House .	767.96	2.8853403

UNITED STATES COAST SURVEY — *Geographical Positions* — Continued.

NAME OF STATION.	Latitude.	DM.	Longitude.	DP.	Azimuth.	Back Azimuth.	TO STATION.	Distance.	Logarithms.
	° ' "	Meters.	° ' "	Meters.	° ' "	° ' "		Meters.	
Lowell Draw . . .	42 22 3.163	97.6	71 3 47.362	1083.6	283 31 17.8 232 41 54.6	103 31 35.8 52 42 9.4	Fitchburg Depot Waverley House	630.20 632.13	2.7904800 2.8008076
North-eastern Ventilator on Eastern R.R. Car Shed.	42 22 7.964	245.7	71 3 39.468	903.0	304 21 43.7 233 54 16.1	124 21 56.4 53 54 25.6	Fitchburg Depot Waverley House	523.50 338.81	2.7189170 2.6007703
Iron Crane, Eastern Rail- road Bridge.	42 22 3.936	121.5	71 3 35.363	809.1	296 51 8.0 212 26 35.8	116 51 18.0 32 26 42.5	Fitchburg Depot Waverley House	379.09 425.63	2.5787429 2.6290324
New England Glass Works.	42 22 20.668	637.6	71 4 20.829	476.5	296 30 5.6 277 3 3.7	116 30 46.2 97 3 41.1	Fitchburg Depot Waverley House	1,540.29 1,278.15	3.1876025 3.1065811
Signal Pole, Eastern Rail- road Freight, at Prison Point.	42 22 25.286	780.1	71 3 54.472	1246.2	294 13 33.7 18 22 44.3	114 13 53.3 198 22 39.0	Waverley House Lowell Round House.	729.85 569.87	2.8632317 2.7537732
Powers, Melvin & Co.'s Elevator.	42 22 57.052	1,760.1	71 4 18.965	433.9	316 13 26.0 345 56 49.3	136 14 2.1 165 57 0.5	Waverley House Lowell Round House.	1,771.95 1,567.73	3.2484506 3.1982726
Upper Gable of three sheds joined.	42 21 55.434	1,710.1	71 3 50.809	1162.8	145 16 45.2 69 19 9.5	325 16 37.4 249 18 38.3	Lowell Round House. Organ Factory . .	462.58 1,132.86	2.6651882 3.0541779
Finial on Octagonal Build- ing, City.	42 21 35.382	1,091.5	71 3 57.964	1326.6	174 17 39.9 103 42 28.7	354 17 37.0 283 42 2.3	Lowell Round House. Organ Factory . .	1,003.88 922.45	3.0016830 2.9649426
Smoke-pipe on new two- story house, Mill-dam.	42 20 54.310	1,675.2	71 5 31.930	730.9	220 9 34.4 135 47 21.7	40 10 11.3 315 46 58.7	Organ Factory . . Nealy's House . .	1,944.23 1,121.71	3.2887481 3.0498812
Long Wharf Cupola . .	42 21 35.108	1,083.1	71 2 36.386	832.7	330 58 24.6 66 27 8.6	150 58 34.0 246 27 1.4	So. Boston Sea wall . State Street . .	659.08 266.32	2.8189414 2.4254015

Cunard Wharf . . .	42	21	48.010	1,481.1	71	2	6.908	157.8	{	20	0	16.6	200	0	6.2	So. Boston Sea wall . . .	1,036.92	3,0137460
									{	61	13	46.1	241	13	19.0	State Street . . .	1,047.99	3,0203574
National Dock, corner brick building	42	22	0.956	29.5	71	2	12.491	285.8	{	9	22	55.7	189	22	49.0	So. Boston Sea wall . . .	1,392.41	3,1437684
									{	41	11	13.4	221	10	50.1	State Street . . .	1,201.02	3,0795485
Bay State Iron Works .	42	20	22.784	702.9	71	2	1.238	28.3	{	239	34	8.1	59	35	16.3	Governor's Isl'd (1877)	2,685.56	3,4290355
									{	153	44	27.7	333	43	56.8	State Street . . .	2,369.60	3,3746751
Ventilator on round building, city.	42	20	48.290	1,489.7	71	3	6.124	140.2	{	261	24	42.5	81	26	34.4	Governor's Isl'd (1877)	3,843.55	3,5847321
									{	198	3	35.0	18	3	47.8	State Street . . .	1,407.41	3,1484207
Peck's Chimney . . .	42	22	49.114	1,515.2	71	2	42.576	974.1	{	267	53	4.1	87	53	40.3	E. B. Reservoir (1877)	1,230.11	3,0899425
									{	190	15	25.5	10	15	30.7	Naval Hospital . . .	987.58	2,9945739
Chelsea Bridge . . .	42	22	54.576	1,683.7	71	2	34.602	791.6	{	276	42	32.4	96	43	3.3	E. B. Reservoir (1877)	1,054.09	3,0228757
									{	179	32	5.4	359	32	5.2	Naval Hospital . . .	803.30	2,9048779
Coal Shed, Chelsea . .	42	23	4.585	141.5	71	2	18.137	414.8	{	302	48	32.3	122	48	52.1	E. B. Reservoir (1877)	797.45	2,9017055
									{	50	38	32.0	230	38	20.9	Chelsea Bridge . . .	487.09	2,6876052
Iron Pipe, Chelsea . .	42	23	12.086	372.9	71	2	5.031	115.1	{	330	49	22.9	150	49	33.8	E. B. Reservoir (1877)	759.91	2,8807604
									{	51	23	7.1	231	22	47.2	Chelsea Bridge . . .	865.66	2,9373481
Winslow's Factory . .	42	23	0.237	7.3	71	3	32.898	752.5	{	235	22	57.0	55	24	19.2	Powderhorn (1877)	3,387.05	3,5298218
									{	277	7	23.9	97	8	34.0	E. B. Reservoir (1877)	2,398.81	3,3799967
Malden Bridge . . .	42	23	9.422	290.7	71	3	52.436	1199.4	{	243	5	50.0	63	7	25.4	Powderhorn (1877)	3,626.66	3,5595069
									{	281	36	23.5	101	37	46.8	E. B. Reservoir (1877)	2,886.21	3,4606276
Brick Factory . . .	42	23	43.140	1,330.9	71	3	51.824	1185.4	{	259	26	0.2	79	27	35.2	Powderhorn (1877)	3,275.72	3,5153068
									{	299	57	2.0	119	58	24.9	E. B. Reservoir (1877)	3,246.78	3,5114524
Round brick building, Charlestown.	42	23	12.828	395.7	71	4	8.756	200.3	{	246	56	4.7	66	57	51.1	Powderhorn (1877)	3,920.77	3,5933719
									{	282	5	27.4	102	7	1.7	E. B. Reservoir (1877)	3,273.09	3,5149585
St. Mary's Church, north spire, city.	42	21	52.836	1,630.0	71	3	8.632	197.5	{	209	8	43.0	29	9	48.8	Powderhorn (1877)	4,583.95	3,6612399
									{	277	28	7.1	97	28	57.1	E. B. Elevator . . .	1,711.83	3,2334615

UNITED STATES COAST SURVEY — *Geographical Positions* — Concluded.

NAME OF STATION.	Latitude.			DM.	Longitude.			DP.	Azimuth.			Back Azimuth.			TO STATION.	Distance.	Logarithms.	
	°	'	"		Meters.	°	'	"		°	'	"	°	'	"			
Lowell Depot, flag-staff .	42	21	51.828	1,598.9	71	3	26.056	596.3 {	Meters.	275	12	54.3	95	13	56.0	E. B. Elevator .	2,104.73	3.3231964
										304	53	11.4	124	53	37.7	State Street .	1,087.78	3.0365401
"P.C." (South Boston Flats)	42	21	12.046	371.6	71	2	35.202	805.6 {		245	12	7.7	65	12	16.3	So. Boston Sea wall .	322.45	2.5084602
										155	51	30.7	335	51	22.7	State Street .	663.15	2.8216095
"C." South Boston Flats .	42	21	7.762	239.5	71	2	25.310	579.2 {		193	56	17.1	13	56	19.1	So. Boston Sea wall .	275.50	2.4401178
										120	16	38.6	300	16	31.9	"P.C." So. Boston Flats	262.11	2.4184912



The observations have all been made by Mr. McClintock and myself ; and experience has shown that there is no sensible difference in our habits of observing. In the record-books the observations marked + were made by me ; all not so marked were made by Mr. McClintock. It was our aim to make thirty-six measurements of each of the principal angles, dividing them into six sets, of six repetitions each, three direct and three reversed, the verniers always being read before reversal. Of the less important angles, twenty-four, eighteen, or twelve measurements were made.

At the beginning of the work the Coast Survey theodolite No. 12 was used. It is a repeating instrument, made by Gambey of Paris: its horizontal circle is six inches in diameter, and is graduated to be read to ten seconds of arc by two equidistant verniers. The superior construction of this instrument is well known ; but, owing to its low telescopic power, it was not suitable for use on the longer lines of our work. Most of the angular measurements were made with a new theodolite, constructed for the Board, with special reference to the work, by Messrs. Buff & Berger of Boston. It is a repeating instrument, with a horizontal circle eight inches in diameter, graduated to be read to ten seconds of arc by two equidistant verniers ; but it is easily read to five seconds by estimation. The object-glass has a clear aperture of an inch and a half, and a focal length of about eleven inches, which allows the telescope to be revolved in its bearings without making the wye standards of an unusual height.

There are two achromatic eye-pieces, the magnifying powers of which are thirty and twenty-two diameters. The one of lower power was used throughout the work. The intersection of the spider-lines is such that the vertical angles are of sixty degrees.

The angles of the main triangle, Blue Hill, Prospect Waltham, and Powderhorn, were measured with this instrument ; and, when corrected for spherical excess, they “ close ” that triangle within forty-nine hundredths of a second of arc. Their probable errors, as computed by the method of least squares, are 0".32 at Blue Hill ; 0".23 at Prospect Waltham ; and 0".46 at Powderhorn. These results have been given elsewhere in this report ; but I repeat them here, as perhaps the best proof that can be given of the superior construction of the Buff & Berger theodolite.

That you may readily form an opinion as to the general accuracy of the triangulation, I respectfully call your attention to the close agreement of the lengths of such of its lines as are determined through different series of triangles from the original base, and to the results of an entirely independent test which was made a few weeks ago, after the field-work had been otherwise finished.

Mr. Edward S. Philbrick, engineer in charge of the enclosure and filling of what is known as the *twenty-five-acre piece* of South Boston Flats, in his report upon the completion of that improvement (Appendix A, Annual Report of Massachusetts Board of Harbor Commissioners, 1877), refers all the points and lines defining the same to a certain base-line, measured upon the flats by his assistant, Mr. Joseph O. Osgood. The connection of this line with our triangulation, through a triangle side removed nine steps from the original base, Blue Hill to Prospect Waltham, is the test above referred to.

The length of the South Boston Flats base-line, as measured by Mr. Osgood, is 860.00 feet. The following are his notes upon its measurement as prepared for the Harbor Commissioners' report : —

- C. Copper tack in the top of a wooden post 6 inches square, set eight feet in the ground. It is at the centre of the curve of 910 feet radius in the Commissioners' line, and is 67.65 feet from south-east corner of State dock-wall.
- P.C. Copper tack in the top of a wooden post 6 inches square, set 4 feet in the ground. It is at the P.C. (beginning) of curve of 860 feet radius, and 22.35 feet back from front top line of caps of Fort Point Channel light wall.

Standard of measurement used is the city standard 100 feet measurement, back of City Hall. Corrections made for temperature.

The length of this line C. to P.C., as determined from our triangulation, is 859.96 feet; differing but four-hundredths of a foot, or a trifle less than half an inch, from the length as measured by Mr. Osgood. The aggregate length of the lines of our work leading from Blue Hill, Prospect Waltham, to the South Boston Flats base-line, is about 62 miles.

The results embodied in this report are derived from two entirely independent computations of the original observations. These computations were made by Mr. McClintock and myself, and by careful comparison and revision were made to exactly agree.

The computations which accompany this report are my own, and the records are the original field-books of the triangulation. Mr. McClintock's computations accompany the carefully prepared duplicates of these records, together with a copy of this report; all of which I will hold until you are pleased to instruct me as to the disposition which shall be made of them.

During its progress, much interest in the work has been shown by local engineers in the vicinity of Boston. At Somerville the Coast Survey station was necessarily established upon a bluff which will probably be graded down some 18 or 20 feet during the next few years. We had not, therefore, regarded it as one of the permanent stations; but, when visiting it for the purpose of providing a temporary marking, we were requested by Mr. G. A. Kimball, city engineer, to furnish points of reference which would enable him to permanently mark the station. His request was complied with, and a substantial granite monument is now in position. Mr. Kimball assures us that this monument will be carefully reset whenever the grading is accomplished.

Mr. Thomas Doane, president Boston Society of Civil Engineers, under date of Nov. 17, 1877, made a written request that a number of points might be determined for the use of local engineers, in connection with the "three-point problem;" and his request was complied with so far as could be done without entailing additional expense upon the survey.

Following are the statistics of work done by my party : —

Stations occupied . . . . .	23
Signals erected . . . . .	23
Points determined . . . . .	49
Angles measured . . . . .	225
Triangles computed . . . . .	89
Number of observations . . . . .	5,868

The total cost of the triangulation to date is about \$2,300.00.

The original records and computations transmitted to you herewith are :—

5 vols. original records of horizontal angles observations.

1 vol. computations of triangulation.

1 vol.<sup>1</sup> descriptions of stations.

While reference to the record-books will inform you of the exact amount of work executed by my assistant, Mr. William E. McClintock, I desire, in closing this report, to make a special acknowledgment of his valuable services. To the zeal and ability with which they have been rendered, the successful accomplishment of the triangulation is largely due.

Very respectfully yours,

FRANCIS BLAKE, JUN.,  
*Assistant United States Coast Survey.*

<sup>1</sup> This volume has yet to be finished by Mr. McClintock, under direction of the Board, and will be forwarded to you as soon as possible.

*Geographical Positions determined during Topographical Survey of Boston Upper Harbor, by William E. McClintock.*

STATION.	Latitude.			Longitude.			Distance.	Logarithms.	Azimuth.			Back Azimuth.			To Station.
	°	'	"	°	'	"	Meters.		°	'	"	°	'	"	
Old Colony Depot . . .	42	20	55.153	71	3	7.857	{ 507.50 1,229.84 }	2.7054370 3.0898481	322 59 31.2 237 44 10.4	142 59 40.2 57 44 41.0	" "	" "	" "	" "	Sugar Refinery. Sea wall.
Way Street . . .	42	20	43.276	71	3	22.152	{ 633.81 491.24 }	2.8019387 2.63912894	273 30 28.3 221 45 30.6	93 30 46.9 41 45 21.0	" "	" "	" "	" "	Sugar Refinery. Old Colony Depot.
N.Y. & N.E. Draw . . .	42	21	0.980	71	2	48.521	{ 600.87 477.64 }	2.7787822 2.6731027	13 11 14.4 67 53 40.7	193 11 10.1 247 53 27.7	" "	" "	" "	" "	Sugar Refinery. Old Colony Depot.
N Y. & N.E. Pipe . . .	42	20	56.812	71	2	43.775	{ 518.36 553.52 }	2.7146323 2.7431364	28 17 42.5 84 41 57.4	208 17 35.3 264 41 41.2	" "	" "	" "	" "	Sugar Refinery. Old Colony Depot.
Maverick House . . .	42	22	9.326	71	2	3.612	{ 1,792.95 2,312.92 }	3.2535681 3.3641006	79 9 26.9 161 59 1.1	259 8 35.0 341 58 40.0	" "	" "	" "	" "	Fitchburg Depot. Naval Hospital.
Lombard's Wharf . . .	42	21	57.636	71	2	11.773	{ 1,574.41 2,614.13 }	3.1971171 3.4173337	90 50 56.6 168 19 52.8	270 50 10.2 348 19 37.2	" "	" "	" "	" "	Fitchburg Depot. Naval Hospital.
Dye Wood . . .	42	22	38.603	71	2	7.322	{ 2,085.26 1,441.44 }	3.3191600 3.1587965	233 29 32.3 154 3 37.5	233 28 42.9 334 3 18.9	" "	" "	" "	" "	Fitchburg Depot. Naval Hospital.
Navy Yard Wharf . . .	42	22	26.965	71	2	37.970	{ 907.30 1,011.57 }	2.9577520 3.0049859	334 38 0.3 309 0 39.9	174 38 2.8 129 1 3.1	" "	" "	" "	" "	Maverick House. Dye Wood.
S. W. Cor. Tall Chimney . . .	42	22	48.768	71	2	10.572	{ 854.00 322.33 }	2.9314589 2.5083024	47 12 36.8 346 39 30.7	227 12 18.3 166 39 32.9	" "	" "	" "	" "	Navy Yard. Dye Wood.
							{ 578.22 1,129.10 }	2.7620972 3.0527337	108 4 12.3 150 29 24.2	288 3 55.4 330 29 8.3	" "	" "	" "	" "	Chelsea Bridge. Naval Hospital.



Church Spire, Stripes, E. B.	Horizontal	42 22 25.327	71 2 2.882	{ 1,862.28 1,856.28 }	3.2927605 3.2680425	64 56 47.2 156 46 23.4	244 55 54.8 336 46 1.8	Fireburg Depot. Naval Hospital.
McQuesten & Fogg	. . .	42 22 26.980	71 2 12.381	{ 592.57 376.82 }	2.7727411 2.5761299	98 56 30.4 197 53 3.9	278 56 13.2 17 53 6.3	Navy Yard. Dye Wood.
Gable Atlantic Works	. . .	42 22 19.016	71 2 18.038	{ 567.46 652.16 }	2.7539356 2.8143529	126 32 6.0 202 4 43.2	306 31 52.6 22 4 50.4	Navy Yard. Dye Wood.
Atlantic Works Pole	. . .	42 22 16.602	71 2 12.893	{ 706.45 690.68 }	2.8490797 2.8392761	125 42 25.9 190 37 59.7	305 42 9.0 10 38 3.5	Navy Yard. Dye Wood.
N. Ship Ho. Pole, Navy Yard	. . .	42 22 36.930	71 2 41.476	{ 783.02 1,356.22 }	2.8987727 3.1323290	266 12 58.9 186 22 39.4	86 13 21.9 6 22 43.8	Dye Wood. Naval Hospital.
Gerrish's Wharf	. . .	42 23 4.460	71 2 18.384	{ 480.24 800.12 }	2.6814565 2.9031574	50 34 24.6 302 21 17.1	230 34 13.7 122 21 37.0	Chelsea Bridge. East Boston Reservoir.
Condor	. . .	42 22 55.854	71 2 6.447	{ 645.20 380.86 }	2.8096934 2.5807608	86 29 42.2 134 12 11.4	266 29 23.2 314 12 3.4	Chelsea Bridge. Gerrish's Wharf.
Chelsea Draw Post	. . .	42 23 5.688	71 2 28.713	{ 368.37 1,024.33 592.81 }	2.5662846 3.0104392 2.7729130	21 26 48.1 297 3 45.6 300 46 49.6	201 26 44.1 117 04 12.5 120 47 4.6	Chelsea Bridge. East Boston Reservoir. Condor
Meridian Street Pipe	. . .	42 23 5.265	71 2 1.976	{ 307.85 376.11 }	2.4883343 2.5753181	19 24 12.5 86 12 56.9	199 24 9.5 266 12 45.8	Condor. Gerrish's Wharf.

[C.]

REPORT OF PROF. HENRY L. WHITING ON THE INSPECTION OF THE TOPOGRAPHY OF THE RE-SURVEY OF THE WHARF LINES OF BOSTON UPPER HARBOR.

*To Hon. C. P. PATTERSON, Superintendent United States Coast Survey, Washington, D.C.*

*Dear Sir,*—I present herewith a report of the completion of the topographical work connected with the re-survey of the wharf-lines of Boston Upper Harbor by the honorable Board of Harbor Commissioners, which, at their request, you directed me to supervise.

This part of the survey has been executed by Mr. William E. McClintock, formerly of the Coast Survey, assisted by Mr. William T. Blunt, the assistant engineer and clerk of the commission. The working force of the field party has been reduced to the minimum; and, while the survey has been carried on efficiently, it has been done at less current expenditure than was allotted to it in the original estimate for this branch of the work. The result has been, that, while the greater cost of the triangulation left a reduced allowance for the topography, as much work has been done, and as large a part of the harbor frontage gone over, as was projected in the original plan of work.

The accuracy and style of this survey are of the first order, and the details minutely represented. These include the marginal ground between the outer faces of the wharves and the first street bordering the general wharf line. Within this space the outlines of all structures are determined. By a system of conventional signs, the character of each structure is expressed,—in wharves, distinguishing between pile-work and solid filling; and in buildings, between wood and brick or stone. This marginal work embraces a large amount of detail of value in the study and treatment of change and improvement in the harbor frontage.

After consideration a larger scale was adopted by the commission for the maps of the re-survey than that used in the survey of 1860, '61, '62, by Mr. Boschke for the United States Advisory Council, which was  $\frac{1}{2400}$ . The change from this scale was mainly for the purpose of conforming to the metric system in measurement. The re-survey just made is contained upon twelve original plane-table sheets, on full-sized antiquarian paper, and fully occupying their space. Eleven of these sheets are on the scale of  $\frac{1}{1000}$ , and include Fort Point Channel from Dover Street Bridge to its mouth, the South Boston sea walls and dock, the frontage of the city proper, Charles River from the Navy Yard to West Boston Bridge, Chelsea Creek from the Navy Yard to Meridian Street and Chelsea Bridges, with the improvements of the Lowell Railroad Company, and the south

channel of Mystic River, and the frontage of East Boston. One sheet, on the scale of  $\frac{1}{20000}$ , includes Charles River, on Cambridge basin, from West Boston Bridge to Brookline Bridge.

In executing the topography on this large scale, it became necessary to add to the original triangulation of Mr. Blake by interpolated points along the immediate harbor frontage. Eighteen of these new points were determined by Mr. McClintock from the bases given by Mr. Blake. The total number of points of triangulation, as the complement determined in the re-survey, is sixty-seven.

Owing to my required presence with my Coast Survey party on the Hudson River, and the recent closing of the Boston Harbor re-survey, I have neither had the time nor opportunity to verify all of the topography of the latter work. But those sheets which I have examined in the field have proved to be first-class in every respect.

I understand your instructions to authorize my inspection of all the topographical work of this re-survey. It is the wish of the commission that I should do so at a future practicable and convenient time. Some supervision may also be desirable in the final treatment of the original sheets.

The expenses of the survey have been carefully disbursed by the Commissioners; and the work closed with the expenditure of the appropriation made for it.

Respectfully submitted,

HENRY L. WHITING.

[D.]

BOSTON, April 20, 1878.

*To the Honorable Senate and House of Representatives of the United States in Congress assembled.*

The undersigned, Harbor Commissioners of the State of Massachusetts, authorized by law to memorialize Congress in behalf of the protection and improvement of the harbors of that Commonwealth, respectfully represent:

That Scituate Harbor is one deserving protection and improvement.

This harbor is situated at a protruding part of the outward trend of the western shore of Massachusetts Bay, and nearly midway between Boston and Plymouth Harbors, being about thirteen miles from Boston Light, and about fifteen miles from Gurnet Light. In character Scituate Harbor is a shallow fiord, with no tributary inland waters. It is open to the eastward, but protected from the north and north-east by Cedar Point, which is the northern arm of the harbor. A spit makes out from this point, and serves as a further partial breakwater. This point is subject to the wasting action of the ocean, and has already been much reduced. The former light-house, which still remains, — although the light has been discontinued, — is situated upon the end of this point.

Vessels forced upon this part of the coast in stress of weather, sometimes cannot "weather" the Cohasset Rocks and Minot's Ledge, which lie between it and Boston Harbor. Coasters, fishing-vessels, and pleasure boats and yachts, which, in cruising nearer the shore and in running the "gangway" passage through the Cohasset Rocks, pass closer to Scituate, and may make it a harbor when they cannot reach other shelter.

In view of the nature and capacity of Scituate Harbor, a large appropriation and expensive work may not be expedient; but the Commissioners would urge that Cedar Point may be protected from further waste, and that some improvement in deepening the entrance of the harbor may be made.

F. W. LINCOLN.

F. A. NYE.

ALBERT MASON.



## [E.]

## STATEMENT OF OPERATIONS DURING THE YEAR ENDING DEC. 31, 1878, ON WORKS FOR THE IMPROVEMENT OF RIVERS AND HARBORS IN THE STATE OF MASSACHUSETTS, UNDER THE CHARGE OF B'VT. BRIG. GEN'L GEORGE THOM, LIEUT. COL. OF ENGINEERS.

## I.—IMPROVEMENT OF BOSTON HARBOR, MASSACHUSETTS.

Of the work projected for the continued improvement of this harbor, under the appropriation made therefor by the River and Harbor Act of Aug. 14, 1876, there remained uncompleted on the 1st of January, 1878, the following, viz.:—

1. Under a contract made June 4, 1877, with Mr. George W. Townsend of Boston, Mass., for breaking up and removing, to a depth of 23 feet at mean low water, about 290 cubic yards of sunken ledges, situated in the main ship channel at the Upper Middle, and near (above and below) Kelly's Rock, the contractor had completed the removal of the only spur *above* Kelly's Rock (containing  $26\frac{4}{10}$  cubic yards), and 50 cubic yards of the ledge *below* Kelly's Rock; leaving to be completed, on the 1st of January, 1878, the removal of about  $131\frac{1}{2}$  cubic yards of the ledge below Kelly's Rock, and 82 cubic yards of ledge at the Upper Middle.

2. The completion of the removal of the sunken bowlders and ledge scattered over Nash's Rock Shoal (situated in the entrance of Boston Harbor), so as to have a depth of not less than  $20\frac{1}{2}$  feet at mean low water, being an increase of about 7 feet in depth on its shoalest part. About one-half of this work was done by contract in 1876; and, of the remainder, about 320 tons of large bowlders and ledge were removed in Sept. 4 to Nov. 8, 1877, by a submarine party, with vessel and crew hired by the day. Work was then suspended for the winter; leaving only about 45 tons to be removed for the completion of the work, which was entirely completed in August last.

On the 8th of April, 1878, Mr. Townsend commenced work under his contract for the removal of the sunken ledge at the Upper Middle, of which he had broken up and removed, up to the 1st of July, 50 cubic yards; and on the 20th of August the remaining 32 cubic yards were completed by him. He then resumed work upon the ledge below Kelly's Rock, and continued until the 1st of December, 1878, when he suspended work for the winter, on account of the boisterous and unfavorable weather; he having, since the 20th of August, broken up and removed to grade 107 cubic yards of this ledge, making altogether 157 cubic yards of it removed by him to date, and leaving but  $24\frac{1}{2}$  cubic yards of it to be done, for the entire completion of his contract.

The sea wall, which was built in 1868 and 1869 for the protection and preservation of the south-east bluff of Lovell's Island, having been so much damaged by the violent easterly gales to which it is exposed as to render its reconstruction necessary for a length of about 600 feet of its southern part, it was decided to increase its height 4 feet (two courses), and to give additional thickness to it by means of concrete backing ; also to protect its foundation, and the stone in front of it, by means of a rubble-stone apron ; and to protect and preserve the bluff in its rear by a substantial paving of large blocks of split granite firmly imbedded in gravel and shingle. Proposals were invited on the 9th of May last for all the stone required for this work, for which seventeen bids were received, and opened on the 31st of May. Contracts were made with the lowest responsible bidders for the same, as follows, viz. : —

With Mr. Isaac A. Sylvester of Quincy, Mass., for furnishing and delivering at Lovell's Island, —

5,700 cubic feet, more or less, of dimension-cut granite, at 39 cents per cubic foot ; and 500 tons, more or less, of split granite, for paving, at \$1.80 per ton of 2,240 pounds.

Also with the Cape Ann Granite Company of Gloucester, Mass., for

1,100 tons, more or less, of rubble-stone, at 59 cents per ton of 2,240 pounds.

All this stone has since been furnished and delivered under the contracts. A wharf was built on the south side of Lovell's Island for the purpose of receiving the stone ; also a railway about 1,000 feet in length, leading from the wharf to the most northern end of the sea-wall. This work was carried on with hired labor from the middle of June until the 9th of December, when it was suspended to be completed next spring. The reconstruction of the sea-wall (proper) has been completed, as well as the rubble-stone apron in front of it ; and the filling back of the wall has been completed to the height required for the back paving, leaving only the paving to be laid next spring, all the stone for which is now on hand. This work has, in part, been done under the appropriation of \$55,000 made for the improvement of this harbor by the River and Harbor Act of June 18, 1878.

Under this same appropriation contracts have been made for the completion of the works, upon the estimates for which the appropriation was based, viz. : —

1. On the 15th of August, 1878, with Mr. Joseph E. Bartlett, the lowest of eight bidders for the removal of Man-of-war Shoal (situated in the upper harbor at the confluence of Charles and Mystic Rivers) to a depth of 23 feet at mean low water by 65,000 cubic yards, more or less, of dredging at 27 cents per cubic yard as measured in scows, the same to be completed on or before the 10th of June, 1879.

2. On the 26th of August, 1878, with Mr. Isaac A. Sylvester of Quincy, Mass., the lowest of three bidders, for breaking up, and removing to a depth of 23 feet at mean low water, a sunken ledge situated near Kelly's Rock, containing 145 cubic yards, more or less, at \$43 per cubic yard measured *in situ*, the same to be commenced on or before the 15th of April, 1879, and to be completed on or before the 1st of December, 1879.

Dredging operations were commenced at the Man-of-war Shoal on the 26th of August last, and have been carried on, day and night, up to the present time, resulting in about 35,000 cubic yards to date under the contract, whereby the work for the removal of this shoal is about one-half done. The contractor purposes to continue these operations throughout the winter unless prevented by ice or other difficulties.

It having been found necessary to make some repairs on the several sea walls built on the north head of Lovell's Island, Gallop's Island, the north head of Long Island, the north head of Deer Island, and on Rainsford's Island, this work was commenced on the 17th of September, and completed to the extent deemed necessary on the 29th of November; it having been done by hired labor, and with material purchased in open market.

From the foregoing statement it is seen that the only work that now remains to be completed under the appropriations of Aug. 14, 1876, and June 18, 1878, consists of —

1. The completion of the dredging at the Man-of-war Shoal, now about one-half done;
2. The breaking up and removal of about  $24\frac{1}{2}$  cubic yards of sunken ledge below Kelly's Rock, under contract of June 4, 1877; and
3. The breaking up and removal of about 145 cubic yards of sunken ledge below Kelly's Rock, under contract of Aug. 26, 1878.

The work done previous to January, 1878, for the improvement of this harbor, in addition to the several works above described, consists of the following; viz., —

I. — The main ship channel has been straightened, widened, and deepened, so as to have a width of not less than 600 feet, and a depth of 23 feet at mean low water at the following places: viz., —

1. At the west end of Great Brewster Spit;
2. At the south-east and south-west points of Lovell's Island;
3. At the Upper Middle Bar;

whereby this channel, from the entrance of the lower harbor up to Anchorage Shoal, has a width of not less than 600 feet, and a depth of 23 feet at mean low water (or about  $32\frac{1}{2}$  feet at ordinary high water), except at the Lower Middle where it requires widening, and near Kelly's Rock where obstructed by the sunken ledges recently discovered to be  $3\frac{1}{2}$  feet shoal.

II. — *Sea walls* have also been built, for the preservation and protection of the headlands in the harbor, at Point Allerton, Great Brewster Island, Lovell's Island (north head), Gallop's Island, Long Island (north head), Rainsford Island, and Deer Island (north, middle, and south heads); all of which are now generally in good condition.

III. — *Sunken rocks* have also been broken up and removed as follows, viz.: —

Kelly's Rock, Tower Rock, Corwin Rock, the ledges recently discovered at the west end of Great Brewster Spit, and between there and George's Island (all situated in the main ship channel at "the Narrows"), to a depth of 23 feet at mean low water. Barrel Rock in Broad Sound, State and Palmyra Rocks situated about one-half a mile east of Castle Island, have also been removed.



Surveys and estimates have also been made and submitted to the U. S. Engineer Department, and an appropriation has been asked for the additional works for the improvement of this harbor, viz.:—

1. Deepening and widening the main ship channel at Anchorage Shoal (next above the Upper Middle) to a depth of 23 feet at mean low water, for an average width of 1,100 feet; this width being necessary, in this central position of the harbor, to enable vessels on entering or leaving the main channel to have free communication with all parts of the harbor, above and below, the estimated cost of which is . . .	\$90,000.00
2. Increasing, to a width of 600 feet, the main ship channel at the Lower Middle, the estimated cost of which, is . . .	5,000.00
3. Straightening, widening, and deepening the main channel near the Navy Yard and mouth of Mystic River, so as to have a depth of 23 feet at mean low water, for a width of 300 feet, the estimated cost of which is . . .	70,000.00
Total	\$165,000.00

## II. — MERRIMAC RIVER, INCLUDING THE HARBOR OF NEWBURYPORT, MASSACHUSETTS.

The project adopted for the improvement of this *river* consists in deepening its shoals by dredging, and the removal of sunken rocks from its channel, so as to afford a depth of 12 feet at ordinary high water, from its mouth in Newburyport Harbor in Massachusetts, up to Haverhill (a distance of 15 miles), and thence for a distance of about 4 miles, up through “the falls,” a depth of 4 feet in the ordinary stages of the river; and that for the improvement of Newburyport Harbor consists in the removal of the Gangeway Rock and the North (Gangeway) Rocks, to a depth of 9 feet at mean low water, the removal of the “Boilers” (a sunken ledge near the city wharves) to a depth of 5 feet at mean low water, and other obstructions to navigation lying in the main channel near the mouth of Black Rocks Creek, and elsewhere.

For the improvement of the river above Newburyport Harbor, the following work has been completed, to date, viz.:—

The channel completed at Hazeltine Rapids, Lower Falls, and Upper Falls (above Haverhill, Mass.), so as to be navigable through “the falls” for a depth of 4 feet in all stages of the river, except in an unusually low stage, resulting from shutting off the water at the Lawrence Mills on Sundays and at night; shoals dredged, and sunken bowlders removed from the channel at and near Rock’s Bridge ( $6\frac{1}{2}$  miles below Haverhill), including Little Currier Rock above, and Petty Rock below the bridge, greatly improving this, the most dangerous part of the river below Haverhill; the channel opened by dredging, for a width of 100 feet, to the projected depth, viz., 12 feet at ordinary high water, at Currier’s Shoal (distant about 5 miles below Haverhill); also to the same depth, and for a width of 75 feet, at the shoals near the head and foot of Silsby’s Island, from 1 to 2 miles below Haverhill. The shoal between the two bridges at



Haverhill has also been improved by dredging so as to have a channel 10 feet in depth at ordinary high water, and numerous large bowlders have been removed from the channel at and near "the falls" above Haverhill; also about 80 tons of bowlders have been removed from the channel near the head of Silsby's Island.

For the improvement of Newburyport Harbor, the following work has also been done, viz.:—

1. The Gangeway Rock, for the most part reduced to grade in the year 1870, and the sunken wreck of the schooner "Globe," entirely broken up and removed in the same year. Under the appropriation of \$10,000, made by the River and Harbor Act of June 18, 1878, a contract was made Aug. 10, 1878, with Mr. Isaac A. Sylvester of Quincy, Mass. (the lowest of five bidders), for breaking up and removing, to a depth of 9 feet at mean low water, 300 cubic yards, more or less, of the North (Gangeway) Rocks, at \$28 per cubic yard, measured *in situ*. Work was commenced under this contract on the 24th of August, 1878, and prosecuted up to the 20th of December, whereby about 170 cubic yards of the rock has been removed to grade, with a probability of the completion of the contract in the time required, viz., not later than the 30th of June, 1879.

The work then remaining to be done for the further improvement of this harbor will consist of,—

1. Completing the breaking up and removal of about 160 cubic yards of the North (Gangeway) Rocks, to a depth of 9 feet at mean low water.

2. Completing the removal of the main "Gangeway Rock," to a depth of 9 feet at mean low water, where shown by recent surveys to have (in one place) less than the required depth.

3. Breaking up and removing about 350 cubic yards of "The Boilers" to a depth of 5 feet at mean low water.

4. Removing four dilapidated sunken piers, abreast of Black Rocks Creek,—they being formidable obstructions to navigation,—one of them having but 6 feet of water over it at mean low water.

5. Removing a very large bowlder, 15' x 13', by 7' high, which lies in 15 feet of water, in the main channel between the north and south piers, and has but 8 feet of water over it at mean low water.

The appropriation of \$10,000, made for this harbor by the River and Harbor Act of June 18, 1878, will all be applied to the partial removal of the North (Gangeway) Rocks, to the extent contracted for; and for the further improvement of the harbor, the additional sum of \$15,000 has been asked, for the fiscal year ending June 30, 1880.

### III.—IMPROVEMENT OF PLYMOUTH HARBOR, MASSACHUSETTS.

The existence of this harbor depends entirely upon the protection and preservation of Long Beach; which is a narrow strip of land that extends  $2\frac{3}{4}$  miles out from the mainland, in a north-westerly direction, nearly parallel to the shore of the town of Plymouth, and distant from it about one mile. It affords to the harbor its only shelter from easterly storms. In late years it has been washed away in some places, and much

weakened in others, to an extent seriously threatening the ruin of the harbor. For the protection and preservation of this beach, various works have been built, from time to time, until finally they have proved efficient and successful.

These works consist of bulkheads, jetties, and groins, built for the accumulation of sand, and the planting of beach-grass, also to accumulate sand and give permanency to the beach thus formed; whereby a ridge has been formed throughout the whole extent of the beach, which is for the most part covered with beach-grass, and is now in an efficient condition.

Exposed as this beach is to injury from violent easterly storms, it necessarily requires occasional repairs. For the permanent preservation of the extreme outer end of the beach, near the beacon, a rubble-stone bulkhead has been built. But, owing to its exposed position, the beach has not grown to the extent desired; so that it has been found necessary to extend this bulkhead farther round the end of the beach.

Under the appropriation of \$5,000 made for this harbor by the River and Harbor Act of June 18, 1878, the work for the extension of the stone bulkhead, and the repairs of the other works where necessary, has been carried on from the 20th of August to the end of November last, — the work having been done by hired labor, with stone and other materials purchased in open market. This work has all been completed, with the exception of the stone bulkhead, which has been suspended for the winter, with a probability of its early completion next season.

Under an appropriation of \$10,000 by the River and Harbor Act of March 3, 1875, for the improvement of this harbor, a channel was opened, by dredging from the Middle Ground up to Long Wharf, a distance of about 2,500 feet, to a depth of 6 feet at mean low water (or 16 feet at mean high water), and for a width of 50 feet.

The project originally provided for a channel 100 feet in width, to be extended southward to the mouth of Town Brook, a distance of about 900 feet above Long Wharf, so as to form a basin in front of the wharves of the city, 125 feet in width, with a depth of 8 feet at mean low water.

For the completion of this project, the additional sum of \$25,000 was asked in my last annual report to the chief of engineers, since published by Congress.

#### IV. — IMPROVEMENT OF PROVINCETOWN HARBOR,<sup>2</sup> MASSACHUSETTS.

Under the appropriation of \$1,000 made by the River and Harbor Act of June 18, 1878, for the preservation and improvement of this harbor, operations have been confined to the extension of the stone bulkhead on Long Point, and planting beach-grass at Cove Section along the beach newly formed by the bulkhead and jetties built in 1874. This work was commenced in the latter part of August, and continued until the first of October; in which time 506 tons of rubble stone was placed in the bulkhead, beach-grass planted, and the repairs completed where necessary on all the works built for the preservation and improvement of this harbor; so that they are now in excellent condition, fully answering the purpose

for which they were designed. They will, however, require continual watching and occasional repairs, exposed as they are to injury from the violent storms which at times occur in that locality. For this purpose an additional appropriation of \$1,000 was recommended in my last annual report.

#### V.—SURVEY OF SCITUATE HARBOR, MASSACHUSETTS.

A survey of this harbor, with a view to its adaptability as a harbor of refuge, was made under my direction in September last, as called for by the River and Harbor Act of June 18, 1878; and a special report thereon has been forwarded to the chief of engineers, U.S. Army, together with a map, plan, and estimates for the work.

#### VI.—SURVEY OF CHARLES RIVER, MASSACHUSETTS.

A survey of this river to the head of tide-water, with a view to the improvement of its navigation, was made under my direction in November last, as called for by the River and Harbor Act of June 18, 1878; and a special report thereon has been forwarded to the chief of engineers, U.S. Army, together with maps, plans, and estimates for the work.

## [F.]

## ABSTRACT OF REPORT OF GEN. G. K. WARREN

TO

*Chief of U. S. Engineers, for 1878.*

## B 1.

## IMPROVEMENT OF HYANNIS HARBOR, MASSACHUSETTS.

Hyannis is situated on the south side of Cape Cod, on Nantucket Sound. Hyannis Harbor is the sheltered area between the breakwater and the shore.

This breakwater is about 1,170 feet long, with a depth of 12 feet at mean low water between it and the shore. It was begun in 1828, and continued with few interruptions until 1837; \$70,931.82 having been expended upon it. In 1853 \$5,000 was expended in repairing the east end.

Since 1870 \$37,000 has been expended in rebuilding the part above water, and increasing the width of the part below low water.

Nothing has been done on the breakwater at this place during the fiscal year.

An appropriation of \$3,000 was made by Act of Congress approved June 18, 1878, for continuing the improvement. With this amount it is proposed to strengthen the breakwater by putting riprap granite about its base, so as to increase the slope to one on two on the seaward side, and one on one on the shore side.

A history of this work was given in the Annual Report of the Chief of Engineers for 1875, part ii., pp. 266-268.

The amount then estimated as required to complete the work was \$10,000. This amount, less the amount appropriated this year, is needed to give the work the required width of base.

I would call attention to the importance of putting a light-house on the east end of the breakwater instead of the present one on the shore.

Hyannis is in the Barnstable collection district. Barnstable is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1878, is not known to this office.

*Money Statement.*

July 1, 1877, amount available . . . . .	\$42 94
Amount appropriated by Act approved June 18, 1878 . . . . .	3,000 00
	<hr/>
July 1, 1878, amount expended during fiscal year . . . . .	42 94
	<hr/>
July 1, 1878, amount available . . . . .	\$3,000 00



Amount (estimated) required for completion of existing project . . . . .	\$7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880 . . . . .	7,000 00

## B 2.

## IMPROVEMENT OF WAREHAM HARBOR, MASSACHUSETTS.

This harbor is an estuary joining Buzzard's Bay near its upper or northern end. The part improved by the general government extends from Wareham, where it is crossed by a railway and a highway bridge, neither of which has draws, to Buzzard's Bay, a distance of 2 miles. The improvement of this harbor, which was completed in 1876, was to make a channel 9 feet deep at mean low water, and from 100 to 300 feet wide, in the upper part of the harbor; and 10 feet deep, and from 250 to 300 feet wide, in the lower part of the harbor. The mean rise of the tide is 4 feet. The depth before the improvement commenced was  $7\frac{1}{2}$  feet at mean low water, in a narrow and crooked channel.

A history of the improvement may be found in Annual Report of the Chief of Engineers for 1877, part i., pp. 194-196. The work done under the last two appropriations was at a much less price than estimated, so that we had about \$2,000 remaining on hand when the improvement was completed. With this amount it was deemed best to build a "sand-catcher" along Long Beach, to arrest the sand carried over it by the waves in storms into the harbor. This work was commenced last season, and will be completed in this season.

No further appropriation is needed, unless a greater depth is required than when the plan was adopted.

Wareham is a port of delivery. It is in the New Bedford collection district, and New Bedford is the nearest port of entry. The amount of revenue collected there during the fiscal year ending July 30, 1878, was \$23,762 33.

*Money Statement.*

July 1, 1877, amount available . . . . .	\$2,057 74
July 1, 1878, amount expended during fiscal year . . . . .	1,153 38
July 1, 1878, amount available . . . . .	904 36

## B 3.

## IMPROVEMENT OF NEW BEDFORD HARBOR, MASSACHUSETTS.

This harbor is an arm of Buzzard's Bay on its north shore, and receives the waters of the Acushnet River. It is the terminus of the New Bedford division of the Boston, Clinton, and Fitchburg Railroad, by means of which it has become a large distributing point for anthracite coal. There are also large manufacturing establishments, and it has the largest

whale-fishing fleets of any port on our coast. The population of New Bedford, and Fair Haven opposite it, is about 25,000.

A survey was made by authority of Congress in 1874, a report of which is printed in the Annual Report for 1875, part ii., pp. 283-287. The project submitted was to make a channel 200 feet wide and 15 feet deep at mean low water, from the deep water in front of Fair Haven to the wharves at New Bedford across the shoals, where the ruling depth before was  $12\frac{1}{2}$  feet at mean low water. The mean rise of the tide is 3.7 feet.

The depth of 15 feet was adopted here because that was about all that vessels could carry over the shoals before reaching Fair Haven.

The amount estimated to complete the work was \$24,000.

An appropriation of \$10,000 was made by Act approved March 3, 1875. Contract with the lowest bidder, the Atlantic Dredging Company, for  $17\frac{1}{2}$  cents per cubic yard, made a channel 15 feet deep and 105 feet wide. The line of it is straight from deep water at Fair Haven to Commercial Wharf, New Bedford, the first location being a little changed to secure better ranges for sheering.

Another appropriation of \$10,000 was made by act approved Aug. 14, 1876, but the work was not authorized until the following April. A contract was made with Mr. W. H. Molthrop (Morris F. Brainard doing the work), the lowest bidder, at  $10\frac{1}{4}$  cents per cubic yard. The low price caused delays in executing the contract, and the time had to be extended to June 30, 1877.

The low price not only enabled us to complete the channel to the width first planned, but to increase it to a width of 300 feet, and to extend it nearly 1,000 feet farther up the harbor along the harbor-line in front of the wharves occupied by the whalers, and to the channel leading to the basin above the bridge.

The Reading Railroad Company have done considerable dredging from this new channel to their wharves.

The material dredged by the government was first dumped in Clarke's Cove, afterward east of Egg Islands, both places entirely out of the harbor.

No appropriation was asked for the fiscal year ending June 30, 1879. None is asked for the succeeding fiscal year, as the improvement, as far as authorized, is completed.

The operations in the last fiscal year were superintended by Mr. H. A. Bentley, assistant engineer.

#### *Money Statement.*

July 1, 1877, amount available . . . . .	\$9,654 60
July 1, 1878, amount expended during fiscal year . . . . .	8,852 78
July 1, 1878, amount available . . . . .	801 82

## B 4.

## IMPROVEMENT OF FALL RIVER HARBOR, MASSACHUSETTS.

Fall River, the largest cotton-manufacturing town in the United States, is situated on Mount Hope Bay, an arm of Narragansett Bay. Fall River Harbor is that part of the bay in front of the town. The part improved by the general government lies between the Rodman Wharf and the wharf used by the steamers running to Providence, a distance of about 1,500 feet. The improvement sought was a channel 12 feet deep, and 100 feet wide at the narrowest part, at mean low water, where the depth was from 6 to 12 feet. The mean rise of tide is 4.7 feet. The harbor was surveyed in September, 1873; and a report with plan and estimates submitted by me Dec. 31, 1873, and printed in Annual Report of the Chief of Engineers for 1874, part ii., pp. 284-286.

The amount estimated as necessary to complete the improvement as designed was \$45,000.

By Act of Congress approved June 23, 1874, \$10,000 was appropriated for this work. With this amount the bowlders lying on the surface were removed by contract, at the rate of \$3.50 per ton. The amount removed under this contract was 1,047 $\frac{3}{4}$  tons of bowlders, and 364 tons of gravel and small bowlders. An additional appropriation of \$10,000 was made by Act of Congress approved March 3, 1875. This, with the unexpended funds of the previous appropriation, was expended in removing, by contract, 21,222.19 cubic yards of material, including bowlders of 2 cubic yards and less, at 48 cents per cubic yard, and 136.53 cubic yards of bowlders over that size.

By Act of Congress approved Aug. 14, 1876, \$10,000 was appropriated for this work. This was expended, by contract, during the present fiscal year, in removing 12,857 $\frac{1}{2}$  cubic yards of material, including bowlders of 1 cubic yard, at 55 cents per cubic yard, and 176.34 cubic yards of bowlders over 1 cubic yard in size, at \$8.40 per yard.

The low prices at which the dredging was done enabled us to make a channel 160 feet wide and 12 feet deep, with an additional width of 100 feet 11 feet deep at mean low water, with the \$30,000 appropriated. The original estimate was \$45,000 for a channel 100 feet wide. The cost of dredging was estimated at \$1 per cubic yard: it was done at 48 and 55 cents.

The improvement is now completed with a channel of the depth sought and an increased width.

This improvement is in the Fall River collection district, and Fall River is the port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1878, is \$18,970.05.

The work during the past year has been under the superintendence of Mr. H. A. Bentley, assistant engineer. In November and December, 1875, while the improvement was being prosecuted, tidal observations for a lunation were made in order to establish a mean low water plane, and determine the rise and fall of tide. The following is a table of these observations:—

Date.	High water.	Low water.	Date.	High water.	Low water.
<b>1875.</b>	Feet.	Feet.	<b>1875.</b>	Feet.	Feet.
November 9 .	6.3	2.4	November 24 .	5.9	2.7
10 .	6.7	2.0	26 .	6.9	2.4
11 .	7.0	1.8	27 .	6.8	2.0
12 .	7.1	1.4	29 .	7.0	1.9
13 .	7.4	1.0	30 .	6.2	1.7
15 .	7.5	1.4	December 1 .	6.7	2.0
16 .	7.2	1.0	2 .	6.4	2.3
17 .	6.8	1.3	3 .	6.2	2.7
18 .	6.1	1.5	4 .	6.5	2.2
20 .	5.6	2.1	6 .	6.4	2.4
22 .	6.4	2.0	7 .	6.6	2.1
23 .	6.6	2.5			

Mean rise and fall, 4.7 feet. Mean low water is referred to a bench-mark, which is the top of the foundation-stone at the north-west corner of Massasoit Flour Mill. It is 9 feet 7 inches above mean low water. An arrow cut in the stone points to the mark.

#### *Money Statement.*

July 1, 1877, amount available . . . . .	\$10,256 47
July 1, 1878, amount expended during fiscal year . . . . .	10,256 47

#### B 5.

#### IMPROVEMENT OF TAUNTON RIVER, MASSACHUSETTS.

This estuary, or so much of it as has been improved by the general government, extends from Weir to Dighton, a distance of about six miles, where it joins or widens out into a bay. The name Taunton River is, however, sometimes applied to this estuary as far down as Fall River,  $7\frac{1}{2}$  miles below. At Weir it is spanned by a draw-bridge, with two openings of about 40 feet each. At low water the river is in many places less than 100 feet in width, and before dredging there was not more than 1 foot depth in the shoalest places. The mean rise and fall of tide at Dighton is 5.28 feet ; at Weir, since the improvement, 3.41 feet : before any improvements were made, it was probably not greater than  $2\frac{1}{2}$  feet at the latter place, but the exact range then is not known.

The improvement sought at first was to get small sailing-vessels up to Weir. In 1852 a survey was made by Lieut. Rosecrans ; and in December, 1853, an estimate for a channel 60 feet wide and 4 feet deep at mean low water was submitted by Capt. George Dutton, United States Engineers. In March, 1870, Capt. J. A. Smith, United States Engineers, in a report upon this improvement, estimated for a channel of the same dimensions as that of Capt. Dutton. An appropriation of \$10,000 was made by Congress July 11, 1870, and another appropriation of \$10,000 by Act approved March 3, 1871. These amounts were expended in dredging a channel through the "Needles." On the completion of this dredging, Gen. Thom, United States Engineers, had a survey made, and from this survey made an estimate of the amount of material to be removed to secure a channel 9 feet deep at mean high water up to Weir.



The amount estimated as necessary to be removed was 31,000 cubic yards, or about twice as much as for the improvement of Capt. Dutton in 1853 and Capt. Smith in 1870.

It will be observed that the depth sought in Gen. Thom's plan was 9 feet at high water, while that estimated for by Capt. Dutton and Smith was 4 feet at mean low water. This, with the mean rise of about  $3\frac{1}{2}$  feet at Weir, would give a draught of about  $7\frac{1}{2}$  feet at mean high water.

At the time the first estimates were made, only small sailing-vessels ascended the river at high-water; and the smallest of these only went above the obstructions at the "Needles," the others unloading below. As soon as the channel was dredged through the "Needles," larger vessels were employed, and tugs used to tow them up and down the river.

This work was transferred to my charge July 1, 1872. The appropriation of \$10,000 made by Act approved June 10, 1872, was expended by me in dredging a channel through Burt's Shoal and Pond's Rocks Shoal, 60 feet wide and  $4\frac{1}{2}$  to 5 feet deep at mean low water, in accordance with the plan submitted by Gen. Thom. Surveys were made during the season of the shoals not before surveyed. A set of observations were made to establish the low and high water planes from Dighton to Weir. The appropriations of \$10,000 made by Act approved March 3, 1873, and \$10,000 by act approved June 23, 1874, were expended in dredging and removing bowlders. In April, 1873, a survey was made of the channels dredged, of the shoal above Berkley Bridge, of the obstructions at the "Nook" at Peter's Point, and of Cobb's Shoal at Dighton. No detailed examinations had been made at these points, and only approximate estimates for the removal of the obstructions.

As before stated, vessels are almost invariably towed up and down this river. The tugs, with their vessels and scows, start from Dighton on the flood-tide as soon as they can cross the rocks and shoals in that part of the river, in order to reach Weir by or before high water, and that a new tow can be formed to take down the river on the first of the ebb.

If any delay occurs in taking the tow up, so that they cannot leave Weir until after ebb has commenced, they will not reach the obstructions at and near Dighton until the tide has fallen 2 feet. Here, then, under these circumstances, we would not have secured a 9-foot draught for vessels by making 9 feet depth at mean high water. To do this it was determined to make in the work below the "Needles" 10 feet depth at mean high water.

With the \$10,000 appropriated by Act approved March 3, 1875, a channel 10 feet deep at mean high water was dredged through Cobb's Shoal at Dighton, and of the same depth at Wikamount, and bowlders removed from the "Nook," and the point of the ledge extending into the channel-way at Peter's Point. This completed the improvement designed to allow vessels of 9-feet draught to ascend to Weir at time of mean high water, except the shoal at Berkley Bridge and some bowlders scattered along the channel and in sharp bends.

To do this it was estimated \$5,000 would be required. With 9 feet secured in this river, except on the sand-shoal at Berkley Bridge, which

lacks but a few inches of the required depth, vessels and barges have been employed drawing nearly or quite this depth ; and as the tugs start with them at Dighton before high water, they strike at Berkley Bridge Shoal, and often at new shoals and bowlders above, which probably have 9 feet at mean high water, but not at any lower stage of the tide.

The barges used here are very long, and frequently in making the short turns strike both banks of the channel.

The bowlders are dangerous obstructions ; and with the \$2,000 appropriated by Act of Congress approved June 18, 1878, it is proposed to remove them as far as the funds will pay for. The removal of Berkley Shoal to 10 feet depth at mean high water would allow vessels to go farther up before striking ; but it is deemed best to leave this as a limiting depth, and use the available funds in removing bowlders to give increased depth and width. The improvement of this river will be substantially completed, as designed, to give 9 feet draught with the expenditure of \$5,000, estimated for by me in Annual Report of Chief of Engineers for 1876, part i., pages 205, 206. This will require an appropriation of \$3,000 in addition to the amount now available ; which is asked for the fiscal year ending June 30, 1880.

A larger channel would be desirable, and no doubt will be asked for ; but, with the completion of the improvement as originally designed, I do not feel authorized to estimate for any thing more.

Taunton River is in the Fall River collection district. The amount of revenue collected during the fiscal year ending June 30, 1878, was \$18,970.05.

*Money Statement.*

July 1, 1877, amount available . . . . .	\$100 93	
Amount appropriated by Act approved June 18, 1878 . . . . .	2,000 00	
		<hr/>
July 1, 1878, amount expended during fiscal year . . . . .		\$2,100 93
		100 93
		<hr/>
July 1, 1878, amount available . . . . .	2,000 00	
		<hr/>
Amount (estimated) required for completion of existing project . . . . .	3,000 00	
Amount that can be profitably expended in fiscal year ending June 30, 1880 . . . . .		3,000 00























